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A PROCEDURE FOR INTRODUCING PRODUCTION PLANNING IN THE BRAZILIAN NAVAL GUN FACTORY, BASED UPON A STUDY OF THIS ACTIVITY IN THE UNITED STATES OF AMERICA

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ABSTRACT

The objective of this thesis is to formulate recommendations for the installation of production planning in the Brazilian Naval Gun Factory, based upon the study of this industrial technique in two United States organizations.

The plants studied operated on a close time schedule during the last war, which means that production planning was of major importance in their activity. Every department in the plant was studied to determine how its functions effect production planning; and these functions were also studied in detail.

Information such as the layout of the plant, type of manufacture, methods and standards, processing and flow of orders, and industrial relations policy was acquired throughout the study, especially when they were related to production planning.

After the facts were compiled, they were used to establish a comparison between the two factories selected for study regarding:

a) Organization of the enterprise.

b) Operation of the enterprise.

c) Forms involved in the enterprise.

After this comparison a summary of the actual organization and operation of the Brazilian Naval Gun Factory was presented.

Finally, based upon a study of the activity in the United States, recommendations were outlined for installation of production planning in the Brazilian Naval Gun Factory.

INTRODUCTION

In Brasil, the peacetime naval industrial activity is the nucleus from which a wartime industrial nation must grow.

The industrial might of a nation is of primary importance in its defense. It is therefore indispensable to keep the factories up to date on new ideas, as industry itself has done in widening its horizons from rule-of-thumb and empirical methods to precision scientific techniques.

Not so many years ago the term "industrial engineer", had a limited meaning. However, today the application of motion and time study, production planning, production control, and plant layout is all included under the title of "industrial engineer".

Many advances in these techniques have been made. Many of these advances were reflected in the success of this country in World War II.

The efficient management and operation of the industrial activities in my country is a problem of primary importance to the Navy and to the nation.

An important part of this problem lies in the introduction of industrial engineering in the Navy's factories.

Developments of the last ten years have brought the Industrial Engineering techniques to the forefront in industry throughout the United States.

The purpose of this thesis is to develop a procedure for introducing Production Planning in the Brasilian Naval

Gun Factory, based upon a study of this activity in the United States.

As plants have expanded, the importance of production planning has become more apparent. In order to have an efficient production planning system it is necessary to know all the factors effecting the planning function and to know in advance what problems may arise that will tend to decrease production.

Factors such as volume of production, equipment available, layout of the plant, factory organization, and processing of orders must be known before these problems can be corrected.

These factors can be most easily found by analyzing the production planning system according to a definite procedure.

As part of this investigation a procedure was outlined for obtaining the necessary information from manufacturing plants.

PREPARATION OF THE ANALYSIS PROCEDURE

The preparation of the analysis procedure consisted of making up a list of items which covered all the normal duties of a production planning division. Some items are of a very general nature. Their principal purpose is to obtain information which will show how the production planning system carries out its assigned functions.

In order to have an efficient production planning system it is necessary to know all the factors effecting the production planning division.

These factors include:

a) type and volume of production
b) equipment and facilities available
c) layout of the plant
d) plant organization
e) procedures followed in the production planning division.

These factors can be most easily found by analyzing the production planning system used, according to a definite procedure.

PROCEDURE FOR INVESTIGATING "PRODUCTION PLANNING" IN THE AMERICAN INDUSTRY

First Part.

Determination of the Organization of the Industrial Enterprise.

a) Structure of Organization. Organization charts.
b) Line of authority, degrees of responsibility, and corresponding duties in the organization.
c) Position of production planning in the organization.
d) Communications between the production planning function and other branches of the organization.

Second Part.

Determination of the Method of Operation of the Industrial Enterprise.

a) Manufacturing methods.
b) Plant equipment.
c) Layout of the plant.

Third Part.

Study of the paper work involved in production planning in the Industrial Enterprise.

a) Standard process-sheet
b) Process chart-product analysis.
c) Operator instruction chart.

APPLICATION OF THE PROCEDURE

The proof of the usefulness of any procedure lies in its application to the task for which it is designed.

In order to validate the procedure, it was necessary to carry it out at the factories selected for study.

Two factories were selected, each for the following reasons:

First - The author was familiar with the activities.

Second- The type of work done by the activities was similar.

Third - The type of work done was similar with the work performed in the Brazilian Naval Gun Factory.

Fourth- It was possible to get information from these organizations about a topic that is highly confidential.

The U.S. Naval Gun Factory is a shore establishment controlled by the Bureau of Ordnance.

The mission of the Gun Factory is to design, develop, manufacture, assemble, inspect and test ordnance equipment and also to serve as a source of prototypes of new weapons.

The accomplishment of its mission requires large engineering and research staffs.

The National Forge & Ordnance Co., in Pennsylvania, a civilian enterprise partially subsidized by the Government, manufactures guns of several calibers and types.

A product of these factories was selected, in order to make a study as concrete as possible.

The product selected was the gun barrel.

The difficulty in getting the confidential information necessary for the study was a major problem in this thesis.

SECTION ONE

ANALYSIS OF THE NATIONAL FORGE AND ORDNANCE COMPANY

1. History.

The National Forge and Ordnance Company, in Irvine, Pennsylvania, makes guns as one of its outstanding products.

"In May, 1914, Clinton E. Wilder, who was then superintendent of a machine shop in Erie, Pennsylvania, formed a partnership with Fred McCoy, a machinery salesman, and Frank Gillespie, who owned a small machine shop located in the rear of his residence, to manufacture a metal cutting drill which had been invented by Mr. Wilder.

"As the prospects of building a successful business looked promising, and since the partners wished to expand into a broader field, a new building was procured and machinery purchased suitable for machining a variety of light forged products. These were principally hollow-bored forgings, such as various types of spindles, shafts, and rolls. The forgings were purchased from a local Erie source.

"In 1916 it was decided to make, rather than buy, the forgings which were necessary in their business. At this particular time difficulty was being experienced in obtaining forgings due to the war in Europe, which this country entered in April, 1917.

"As a result, the Irvine Steel Forge Company, located on the present site, was purchased.

"The machine shop in Erie continued to operate for approsimately one year after the purchase of the Forge Plant at Irvine, after which time all operations were conducted in Irvine.

"With the entry of the United States into the first world was, expansion was started.

"A heat treating plant was erected and new machinery added to enable the Company to better meet the requirements of its customers.

"In 1926 full ownership of the Company passed into the hands of Mr. Wilder and the name of the Company was changed from The Natinnal Forge and Tool Company to The National Forge and Ordnance Company.

"The steady growth of this organization has been firmly founded in the reputation for quality NFO products have gained among users of heavy duty forged products.

"The past of the Company represents years of hard work to earn and maintain the position it has achieved.

"The history of the National Forge and Ordnance Company covers more than thirty years of interesting and impressive growth.

"For years the organization has been supplying the industrial markets of the United States and those abroad with heavy duty steel forgings, crankshafts, tubes, shafts, ingots, billets, ordnance materials and many other types of forged steel products."[1]

---

1 - "A Manual for Employees" - National Forge & Ordnance Co., Warren, Penna.

2. Factory Location.

The factory is located in Irvine, Warren County, Pennsylvania, centrally placed with respect to large industrial areas, such as Erie, Buffalo, and Pittsburg.

3. The Market.

The markets in which the products are sold are classified into two types:

a) The national market.

b) The international market.

In the ordnance field the national market consists of the United States Armed Forces.

As an example of the international market we can give Brasil, which bought guns during the last world war.

4. Labor.

The present personnel have been built up and organized with a keen appreciation of forging craftsmanship. Consequently, this organization is composed of approximately 1000 skilled workers intent on making steel forging their life work.

More than thirty years of forging have developed a wide range of experience and an extensive knowledge of how forgings should be made.

Labor is drawn from small nearby towns and rural areas.

It is the policy of the Company to set up and maintain

fair wage differentials between jobs in all departments, based on differences in their relative requirements in terms of skill, effort, responsibility and working conditions.

A job specification is maintained for every job showing the description of duties, the rating of the job in terms of the eleven factors used in the Job Rating Plan, the requirements of each factor which substantiates the rating, the total points scored, and the corresponding labor grade.

An employee receives the minimum of the rate range applicable to his particular job classification as soon as he is able to efficiently perform all the tasks that may be required in his occupation.

Inexperienced men may be classified as learners. Such persons receive training on the job in one specialized occupation, under the supervision of their department foreman who has the responsibility for their proper instruction.

A shift premium is paid on the basic hourly rate to all hourly rated employees.

Standard times are established on productive operations, under the "wage incentive plan".

These standard times have been set with a view toward allowing sufficient time to maintain high quality work. They are based on time study and experience during a certain period of application. They are revised whenever changes in process, methods, tools, or machine tools justify such revision.

An employee or group of employees who have worked on operations for which standards have been set, and who have

performed these operations in less than standard time, are credited with a premium.

In accordance with established policy, individual rate increases are made for the following reasons:

1 - Merit increases within the established rate range applicable to the employee's particular job classification.

2 - Individual promotion or reclassification.

I - DETERMINATION OF THE ORGANIZATION OF THE NATIONAL FORGE & ORDNANCE COMPANY

a)

Structure of the Organization; Organization Charts.

This Company started with a small shop, and only in 1917, with the entry of the United States into the war, was expansion initiated.

The owner, Mr. Clinton E. Wilder, was the manager or superintendent. All men reported directly to him. He was the man who established policies, assigned the jobs to be done, and followed up on the jobs for purposes of direction and coordination.

From 1926 on, the company grew steadily, and during the last world war the business expanded greatly, reaching a critical point in organizational procedures.

Today, all divisions have been coordinated, and all are working toward a common purpose in conformity with established policies.

The Company established a framework of authority and responsibility.

When an enterprise grows in size to a point where one man can no longer exercise direct and personal control over all its activities, he is compelled to delegate authority and responsibility to others.

To facilitate the operation of the organization, consideration must be given to the appropriate assignment of work; both

in terms of manufacturing operations and the abilities and specialized skills of available personnel.

The organizational structure will necessarily vary with the requirements of each company, but a planned organizational structure is indispensable.

To satisfy this necessity, the various functions of the enterprise were outlined and charted in chart Number 1.

The main functions in a manufacturing concern are those of engineering, manufacturing, sales, purchasing, industrial relations, and accounting and finance.

In this company the stockholders, through their board of directors, selected a president who was placed in charge of the formation of the policies of the factory.

Under the President we have the principal groups, called divisions.

The organization was built around functions, not individuals. The activities were blocked out following a representative chart which carries the major functions normally necessary in most manufacturing enterprises.

The following divisions were omitted:

a) Industrial Relations.

b) Industrial Engineering.

The functions generally attributed to these divisions were placed in other divisions.

A breakdown of theEngineering Division was made in order to locate the production planning function in the organiza-

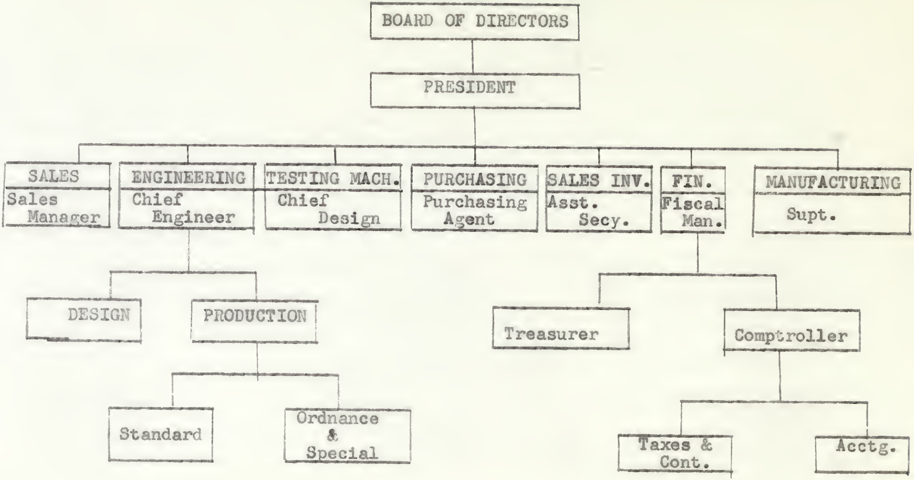

BOARD OF DIRECTORS
PRESIDENT
SALES
Sales Manager
ENGINEERING
Chief Engineer
TESTING MACH.
Chief Design
PURCHASING
Purchasing Agent
SALES INV.
Asst. Secy.
FIN.
Fiscal Man.
MANUFACTURING
Supt.
DESIGN
PRODUCTION
Standard
Ordnance & Special
Treasurer
Comptroller
Taxes & Cont.
Acctg.

CHART No.1 - STRUCTURAL ORGANIZATION OF THE NATIONAL FORGE & ORDNANCE COMPANY

tion. A breakdown of the Manufacturing Division was also made in order to show the communications between the production planning group and the several branches of the manufacturing division, as well as the paper work used by production planning.

Using these charts gives us an idea of how authority and responsibility are carried down to supervisors, foremen, and group leaders.

Seven persons report directly to the president.

The general superintendent, head of the manufacturing division, has under him four departments: personnel, material control, production services, and production. He has one assistant who works as General Superintendent on the night shift.

The Financial Division has two main departments, one of which is headed by the comptroller and the other by the Treasurer.

The Purchasing Division takes care of all inventories except the steel scrap inventory.

The Testing Machines Division is a new division under the control of a "Chief of Design", with the purpose of manufacturing testing machines for tension, compression, flexure and shear.

The Engineering Division, responsible for the preparation of engineering data and drawings, is sub-divided into two departments, Design and Production. These will be studied later.

The Sales Department is divided into Estimating and Scheduling, which are under the supervision of two sales manager's assistants.

b)

LINE OF AUTHORITY, DEGREES OF RESPONSIBILITY AND CORRESPONDING DUTIES IN THE ORGANIZATION

The Overall Structure

Under the President we have the following divisions:

1) Sales.
2) Engineering.
3) Testing Machines Design & Development.
4) Purchasing.
5) Sales Invoicing.
6) Finance.
7) Manufacturing.

To the assistant secretary was delegated the responsibility for carrying out sales invoicing.

The separate divisions are subdivided into departments, each with a designated head.

Sales

The sales division is divided into two departments:

1-1) Estimating.
1-2) Scheduling.

This division also includes personnel qualified for advertising, selling, customer relations and market surveys.

Engineering

In this case, the products require a large amount of research and engineering, and a separate engineering division

reporting directly to the president is justified.

The division is subdivided into:

2-1) Design department.
2-2) Production department.

The Production department is subdivided into:

2-21) Standard Product section.
2-22) Ordnance and special section.

Each department serves a designated function, and all are coordinated in their activities by a "Chief Engineer" as head of the division.

The "Design" department has as its duties:

2-11) Preparation of engineering data.
2-12) Design of the Product.
2-13) Preparation and maintenance of drawings, models, blueprints, and specifications.
2-14) Product simplification.
2-15) Standardization.
2-16) Technical instruction.
2-17) Preparation of bills of materials.
2-18) Research.

The engineering data include calculations pertaining to the performance of the product, its strength characteristics, operating speeds, permissible load, life, etc. The department also prepares specifications for lubrication, servicing, and replacement of parts.

Drawings are prepared for each part, sub-assembly, or assembly; and serve as the foundation of all instructions

issued to the manufacturing units, as well as indicating all necessary dimensions, tolerances, clearances and specifications.

The plant does not have an "Industrial Engineering" division, but the functions are distributed among the other divisions.

It should be noted that the chief engineer has a large amount of work to do and great responsibility. He does not have industrial and plant engineers to help him handle the technical problems of manufacture.

The chief engineer devotes only part of his time to the research work of the enterprise. In this factory, where the amount of research is not great, and is under the supervision of the chief engineer, each manufacturing unit does its own research development. Each research unit is concerned with problems and projects pertaining to the particular manufacturing unit with which it is affiliated.

The other important department of Engineering is called Production, which is sub-divided in two sections: Standard Product, and Ordnance and Special product.

Under the supervision of the chief engineer, the production department has as its duties:

2-21) Development of manufacturing procedures.

2-22) Analysis of operations.

- a) Standard process charts.
- b) Machine load sheet.

c) Operators instruction charts.

2-23) Determination of Time Standards.

2-24) Work Simplification.

2-25) Improvement of existing procedures.

2-26) Preparation of orders.

2-27) Layout.

Purchasing

All purchasing is channelled through one agency, the purchasing department, under the supervision of the purchasing agent. All vendors inquiries and contacts, as well as purchasing commitments, are arranged through the purchasing department. This centralization of purchasing has the following advantages: more efficient ordering of materials, elimination of duplication of effort, and simplification of procedures. The purchasing agent of the company in this type of organization should be able to deal with vendors on technical details, and he should be familiar with the markets that supply the materials.

The types of inventories controlled by the purchasing agent are: raw materials, tools, purchased parts, finished goods, and in-process inventories. These inventories are also under the "Comptroller," who is head of the finance division.

Sales Invoicing

Sales invoicing is a division entirely separate from sales, having as its head an assistant secretary reporting

directly to the president.

Finance

In order to obtain better supervision of its two sections, the Finance Division is split up under two division heads, the comptroller and the treasurer.

The accounting department assumes responsibility for the general and control accounts of the company. The "costs" section includes the recording and analysis of all costs pertaining to the operation of the company. Under the treasurer is the credit section, which takes care of credit ratings for customers. Accounts payable and receivable are divisions of accounting.

The Department of Taxes and Government Controls is significant because of the many federal taxes that affect the company's earnings.

The payroll section is under the accounting department.

Manufacturing

The General Superintendent is in charge of all departments directly related to the manufacture of the product. Reporting to him are the heads of the following departments:

7-1) Personnel.

7-2) Material Controls.

7-3) Production Services.

7-4) Production Departments.

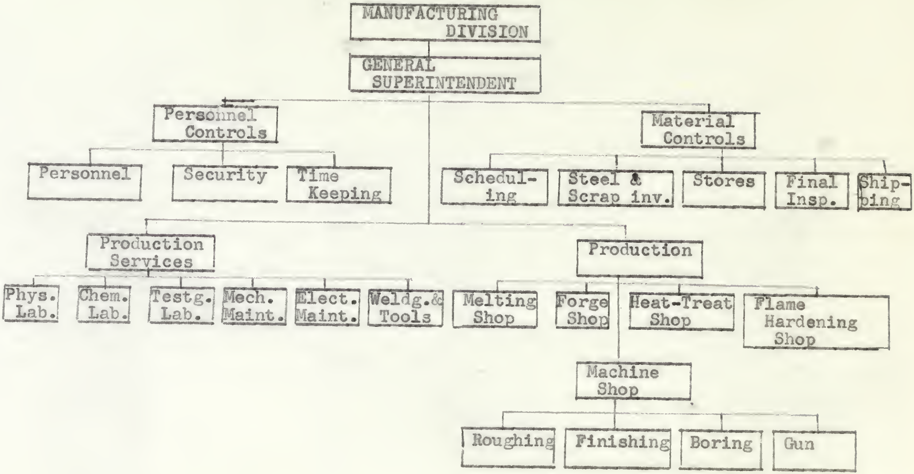

MANUFACTURING DIVISION
GENERAL SUPERINTENDENT
Personnel Controls
Personnel
Security
Time Keeping
Material Controls
Schedul-ing
Steel & Scrap inv.
Stores
Final Insp.
Ship-ping
Production Services
Phys. Lab.
Chem. Lab.
Testg. Lab.
Mech. Maint.
Elect. Maint.
Weldg.& Tools
Production
Melting Shop
Forge Shop
Heat-Treat Shop
Flame Hardening Shop
Machine Shop
Roughing
Finishing
Boring
Gun

CHART NO. 2 - STRUCTURAL ORGANIZATION CHART OF MANUFACTURING DIVISION.

STRUCTURE OF THE MANUFACTURING DIVISION

It may be observed that in this company many more functions are placed under the General Superintendent than in other industrial organizations.

In the production department each foreman is responsible for approximately 120 men.

The assistant superintendent works as a general superintendent on the night shift, but in the line of authority he is under the general superintendent.

In the personnel controls department is included the function of Industrial Relations, which today represents an important part of industrial management. The human aspects of business are coming more and more to the foreground in industrial organizations.

The Personnel Section's duties are:

7-11) Employment.
7-12) Wage administration.
7-121)Job evaluation.
7-122)Merit rating.
7-13) Seniority.
7-14) Job bidding.
7-15) Vacations.
7-16) Leaves, Layoffs, Transfers.
7-17) Terminations.
7-18) First aid.
7-19) Weekly news bulletin.

The Plant Security Section makes every effort to safe-

guard all operations. Dangerous machines are provided with guards. Most accidents are caused by using defective tools, disregarding safety instructions, or neglecting to use safety appliances. Elimination of carelessness, and attention to safety instructions is the goal of this department. It has under its jurisdiction: plant guards, plant safety, fire protection, maintenance of buildings and grounds, trucks, bulldozers, and janitor service. As a matter of policy every employee is considered a member of the Safety Organization, and violation of safety instructions may be followed by disciplinary action, even though the particular violation does not result in an accident.

Another important division in the company is called "Material Controls" and can be compared with "Production Control", which is in general a department of an "Industrial Engineering Division". This material controls division is sub-divided into five departments:

7-21) Production Scheduling.
7-22) Yard and Production Material.
7-23) Supply stores.
7-24) Final Inspection.
7-25) Shipping.

This factory does not have a separate production control division, however there is coordination between the various activities based on the principles of production control. In the production department however, we have the majority of the organs of a production control system. The position of

this department under the Manufacturing Division is sound because "Production Control", as a phase of an industrial program, is concerned with the problem of coordination of the elements of production: labor, material, and production facilities. In this factory, such elements as labor, production services, materials and production sections are under the supervision of the General Superintendent of the "Manufacturing Division".

The Production services are divided into:

7-31) Quality Control.

7-32) Mechanical Maintenance.

7-33) Electrical Maintenance.

7-34) Welding and Cutting tools.

Quality control is not only involved with the setting of the necessary standards of product quality but also with the establishing of an organization and the procedures for sufficient inspection and control to maintain those standards effectively. In other words, they keep the scrap pile as low as possible. In the production of a gun, where the forging costs about $450.00, and the gun barrel about $2,700.00, it is easy to understand the importance of avoiding production interruptions because of poor quality.

There is a tendency in this factory away from manual and toward mechanical inspection. In this, the field of electronics has tremendous possibilities in the control of quality of guns. In this factory the final inspection of all products before shipment is done in a section subordinate to the material controls department. All other kinds of inspection during

the manufacturing process ~~is~~ are under the responsibility of the Production Department.

The Quality Control Section of the Production Services Department is concerned with principles and techniques used to achieve the degree of quality desired with the aid of three laboratories:

7-311) Physical Laboratory - (Metallurgy).
7-312) Chemical Laboratory - (Chemical Analysis).
7-313) Testing Laboratory - (Testing for Physical Specifications).

The Mechanical Maintenance Section is concerned with:

7-321) Machine repair.
7-322) Materials handling repair.
7-323) Boilers and Plumbing repair.
7-324) Yard and Buildings repair.

The Electrical Maintenance Section is responsible for the upkeep of all electrical equipment, including electrical furnaces and power sub-stations.

The Production Department is one of the most important in the organization. It is composed of five shops:

7-41) Melting Shop - steel production.
7-42) Forge Shop - press and hammer forging.
7-43) Heat Treat Shop - all types of heat treatment except flame hardening.
7-44) Flame Hardening Shop - Flame hardening.
7-45) Machine Shop.

The Machine Shop is divided into four groups:

7-511) Roughing Group.
7-512) Boring Group.
7-513) Finishing Group.
7-514) Gun Group.

The production foremen are the heads of the shops and are directly below the General Superintendent. The heads of the machine shop groups are assistant foremen, and are directly below the machine shop foreman. The foremen are responsible for personnel, quality, and production quantity within their departments. They are almost free of clerical work, thus they are free to handle the mechanical problems that arise daily.

Procedure followed in the Study of the Organization:

1) Determination of the type of organization.
   In the National Forge & Ordnance Co., the type of organization is one combination of line and staff.
2) Preparation of the charts of interest to our study.
   Three charts were of interest:
   - 2-1 - The General plan of the organization.
   - 2-2 - Breakdown of the functions of the Manufacturing Division.
   - 2-3 - Breakdown of the Engineering Division, to show the position of the production planning function in the organization.
3) Determination of the number of top-level supervisors reporting to the next higher level.
4) Separation of the staff functions from the line functions.
5) Determination of the number of departments in each division.
6) Determination of the number of sections in each department.
7) Evaluation and presentation in a simple manner of the duties and responsibilities of each key position.

c)

POSITION OF THE PRODUCTION PLANNING FUNCTION IN THE ORGANIZATION

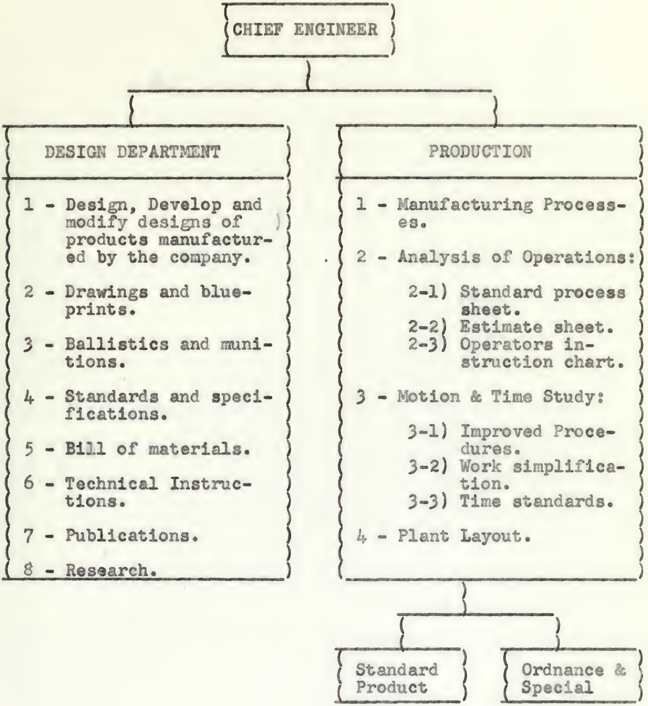
Production planning is the procedure for drawing a complete process sheet, starting from a description of the product to be made and a knowledge of the approximate volume required.

Production Planning is the design of a process.

In the engineering department, under the "Chief Engineer", and with the name of "Production", is located the function called production planning. The Chief Engineer is then the man responsible for production planning in this company. By studying the work performed in the department and by consulting the chief engineer, the main functions performed by production planning within the organization were arrived at. These are:

1) Determination of manufacturing processes.
2) Analysis of operations.
    2-1) Help in preparation of the standard process charts.
    2-2) Estimate of cost.
    2-3) Help in preparation of operators instruction charts.

In the functions already established by this department in the factory in study, the chief engineer decides what has to be done and where, when and how it is to be done.



CHIEF ENGINEER

DESIGN DEPARTMENT

1 - Design, Develop and modify designs of products manufactured by the company.

2 - Drawings and blueprints.

3 - Ballistics and munitions.

4 - Standards and specifications.

5 - Bill of materials.

6 - Technical Instructions.

7 - Publications.

8 - Research.

PRODUCTION

1 - Manufacturing Processes.

2 - Analysis of Operations:

2-1) Standard process sheet.
2-2) Estimate sheet.
2-3) Operators instruction chart.

3 - Motion & Time Study:

3-1) Improved Procedures.
3-2) Work simplification.
3-3) Time standards.

4 - Plant Layout.

Standard Product

Ordnance & Special

CHART NUMBER 3 - Breakdown of the Engineering Division to show the position and functions of production planning in the organization.

In this phase of planning the product is analyzed according to its component parts, and the required manufacturing operations are listed in order to foresee the sequence of steps necessary for its completion. The analysis of operations will aid in obtaining the best possible process before beginning the work.

In this factory, plant layout is also under the supervision of the chief engineer and is done in the production department.

d)

COMMUNICATIONS BETWEEN PRODUCTION PLANNING AND OTHER BRANCHES OF THE ORGANIZATION

A functional analysis of the National Forge & Ordnance Company organization was made with the purpose of determining the lines of communications between the Production planning function and the other branches of the organization. To get an idea of the communication between the production planning function and the other branches of the organization, the best thing is to follow a "Sales Order" from the time it is received in the design department to the time it goes to the shop.

After receiving the sales order, the design department prepares the bill of materials and drawings and makes copies of them.

The originals of the drawings and bill of materials are filed in the design department. Before filing the originals however, copies are made of the bill of materials and drawings and are sent to the office of the chief engineer. In this office are also received the standard process sheets, operator's instruction charts, machine load sheets, and job orders, all of which are prepared in the production department and a file kept.

With the blueprints, bill of materials, standard process sheets, operators instruction charts, machine load sheets and job orders on hand, the chief engineer forwards them to the

manufacturing division.

From the office of the general superintendent of the manufacturing division these data are sent to the material controls department, production services, and production departments.

The Material Control Department receives the "Machine load sheet". Production services can obtain, when necessary, operators instruction charts.

The shops of the production department receive:

a) Blueprints.
b) Bill of Material.
c) Standard Process Sheet.
d) Operator's instruction charts, when necessary.
e) Job order.

As was mentioned before, the items (a) and (b) were prepared by the design department and the items (c), (d), and (e) were prepared by the production planning department, both under the supervision of the head of the engineering division.

II - OPERATION OF THE NATIONAL FORGE & ORDNANCE COMPANY

a)

MANUFACTURE OF THE PRODUCT

2-1 - Introduction

One of the most effective weapons in the last world war was the 5 inch 38 calibre gun. This weapon, a masterpiece of naval ordnance, and a long-time standard on many naval vessels, was designed as an anti-aircraft weapon but at the same time it is very effective against surface targets and enemy land installations.

In order to obtain the accuracy of which the gun is capable it is necessary to work to limits usually found only in small precision parts. An error of only one minute of arc is permitted in the training mechanism. The lateral movement of the mount in the training bearings must be held to within .002 to .004 inches. The elevating arc and pinion are held to a backlash of from .0015 to .0025 of an inch.

2-2- The manufacturing process will be studied in three distinct parts:

2-21- Manufacturing of the ingot.

2-22- Manufacturing of the gun barrel forging.

2-23- Manufacturing of the gun barrel.

2-21 Manufacturing of the ingot

Ref.:
a) Layout of the plant - Figure No. 1
b) Drawing No. 1

The National Forge & Ordnance Co. makes its own steel.

As a result, it is able to control the quality of its steel. It has installed Basic Electric Furnaces for melting the steel, because the electric furnace has very definite advantages over other steel melting methods, such as more uniformly high quality. By the electric method it is possible to hold the chemical analysis within close limits. Cleaner steel can thus be produced, and lower sulphur and phosphorous contents can be obtained.

No steel is poured until the chemical laboratory has checked the analysis of the batch and approved it.

Every half hour after the charge is melted a carbon test is made.

The chemical composition of the steel required to make the 5"/38 gun barrel is as follows:

Carbon .34 to .40%
Manganese .58 to .68%
Phosphorus .03% (maximum)
Sulphur .03% (maximum)
Silicon .20 to .30%
Chromium .80 to 1.10%
Molybdenum .20 to 30%
Nickel .30 to .45%

The important characteristics of this steel are:

a) Unusual ability to resist attack by corrosive media at atmospheric or abnormal temperatures.

b) Unusual strength at elevated temperatures.

The melting furnace is of the electric arc type. The electricity is purchased from the Pennsylvania Electric Co. The incoming lines bring the power to the substation at 3-phase, 33,000 volts where it is then transformed to 1657 volts for furnace use. The furnace runs one shift approximately 8 hours per day, five days per week. It produces two heats each shift and four ingots. The furnace must be operated at night to concerve on the demand from the electric company.

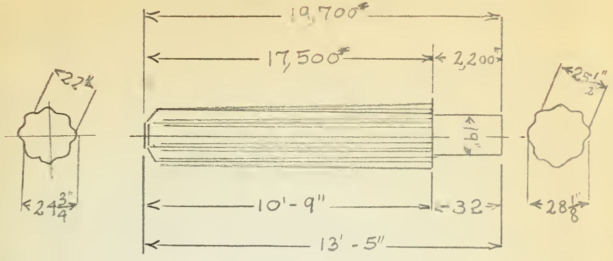
The ingot heating soaking pit, re-heat furnaces, pouring pit, and hydraulic ingot stripper are other component parts of the equipment in this shop.

The furnace charge is made up from the material in the bins, and placed in chutes for a side door for charging the furnace. The charge is weighed on the platform scales to obtain the correct amount.

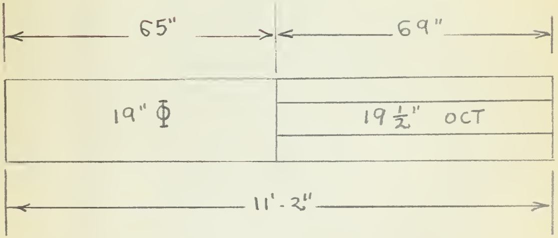
The charge is melted and an analysis is made for the chemical laboratory. After the analysis, the correct addition of alloys is made and the charge is refined. The charge is then poured into a ladle and from there into the ingot moulds located in the pouring pit.

After the steel has cooled sufficiently in the mold, the mold is stripped from the ingot by means of the Hydraulic Ingot Stripper. The ingot is then placed in the Heating Soaking Pit to be heated to forging temperature.

After the ingots are heated to forging temperature they are removed from the Ingot Heating Soaking Pit with pit tongs


19,700#
17,500#
2,200#
22½
24¾"
19"
25½"
28⅛"
10'-9"
32
13'-5"

25½" - 17,500# CORRUGATED INGOT


65"
69"
19" Φ
19½" OCT
11'-2"

LIMITS, UNLESS OTHERWISE NOTED
FRACTIONAL ± 1/64 DECIMAL ± .010 ANGULAR ± ½°

ITEM	NAME	NO PER UNIT	MATERIAL
	5"/38 GUN TUBE		ALLOY STEEL

ENGINEERING DRAWING
AND DESCRIPTIVE GEOMETRY
GENERAL ENGINEERING DEPARTMENT
PURDUE UNIVERSITY
LAFAYETTE, INDIANA

TITLE OF UNIT
CORRUGATED INGOT

SCALE
APPROVED
TRACED BY
CHECKED BY
DATE
DRAWING NO
1

suspended from the Press Crane and placed in the 1250 ton High-Speed Forging Press.

In the manufacture of a gun barrel the ingot must have sufficient weight to make the forging, and 10% extra for heating loss, 5% for bottom crop and 20% for top crop. Crops are the ends of an ingot containing defects which are cut off and discarded.

The ingot should be large enough to give a good reduction when forging. The 25½", 17,500 pound corrugated ingot is shown on drawing No. 1.

The ingot from which the 5"/38 gun barrel is forged is corrugated to the shape of an octagon. A tong hold is left at the top of the ingot to assist in handling.

2-22 Manufacturing of the gun barrel forging.

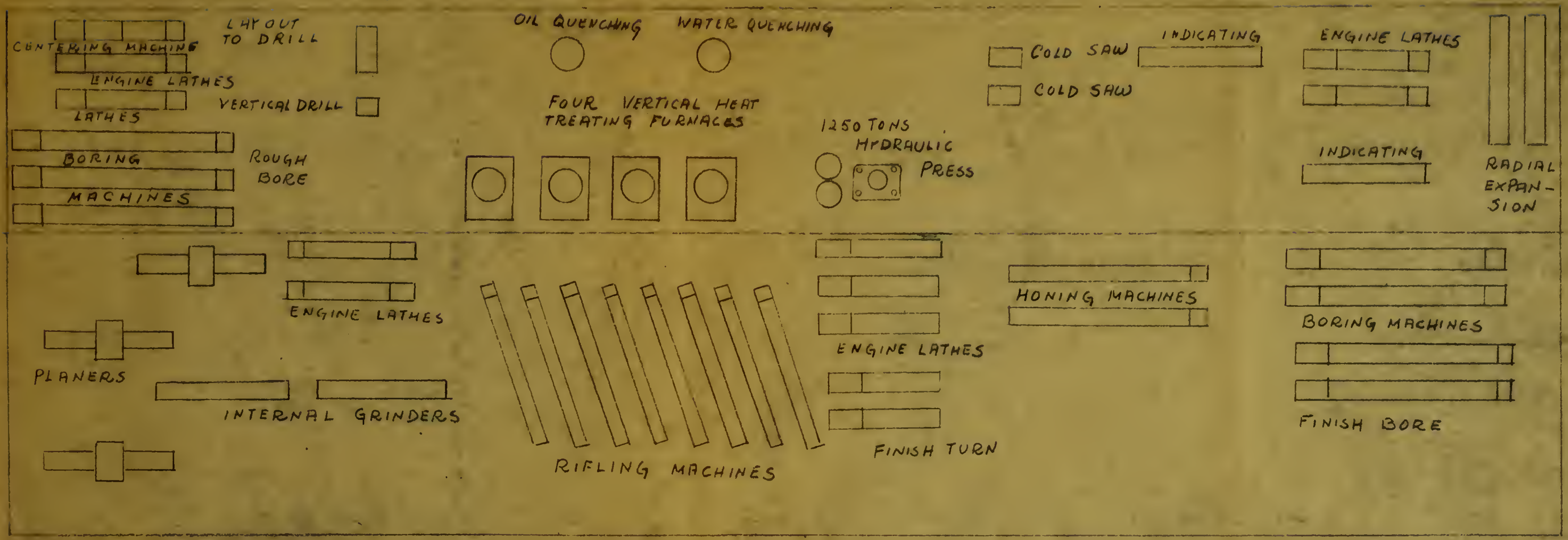
Ref.: a) Layout of the plant - Figure No. 1
b) Drawings Nos. 1, 2, and 3.

After the ingot is poured and allowed to cool it is placed in a suitable heating furnace and heated to forging temperature (approximately 2,250 degrees Fahrenheit). It is then allowed to soak until the heat is uniform. Soaking accomplishes the attainment of uniform temperature throughout the piece.

The ingot is then removed from the furnace. One end is gripped by the jaws of the 10,000 pound straight line manipulator and the ingot is forged to a 19½" octagon in a 1,250 ton, open-die, High-Speed Forging Press. The 19½" octagon is placed in the re-heating furnace and reheated to forging temperature.

After the 19½" ingot has again been heated up to forging

FIG. 1 - LAYOUT - MACHINE SHOP
NATIONAL FORGE & ORDNANCE Co


CENTERING MACHINE
LAY OUT TO DRILL
ENGINE LATHES
LATHES
VERTICAL DRILL
BORING MACHINES
ROUGH BORE
OIL QUENCHING
WATER QUENCHING
FOUR VERTICAL HEAT TREATING FURNACES
1250 TONS HYDRAULIC PRESS
COLD SAW
COLD SAW
INDICATING
ENGINE LATHES
INDICATING
RADIAL EXPANSION
PLANERS
ENGINE LATHES
INTERNAL GRINDERS
RIFLING MACHINES
ENGINE LATHES
FINISH TURN
HONING MACHINES
BORING MACHINES
FINISH BORE

temperature and soaked until the heat is uniform it is withdrawn from the reheating furnace, placed in the press, and forged to the final sizes given on the final forging drawing. The forging is then buried in ashes and allowed to cool slowly. When cool, the forging is taken to the cold saw and an etch disc cut from each end. The disc is then etched in acid and examined for inclusions.

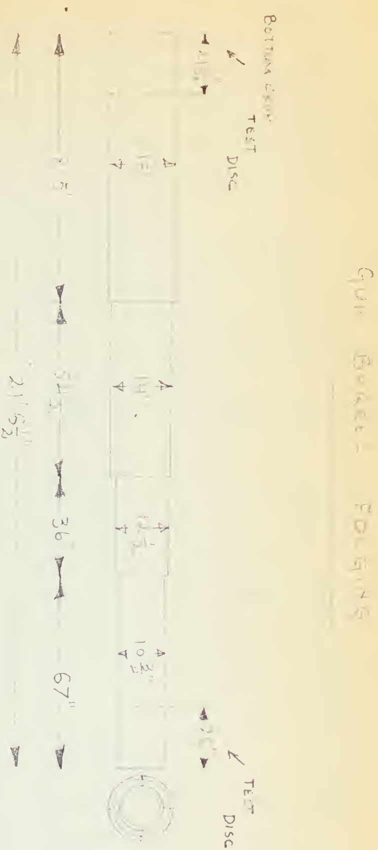
The disc is one inch thick, machined and polished on one surface, and then etched with hot diluted hydrochloric acid. The examination of the disc is done under a microscope to determine whether the steel contains any non-metallic inclusions or defects that could be injurious to the gun barrel.

In the hydraulic forging press the pressure is applied slowly, allowing time for the flow of metal, and the effect penetrates deeply into the metal.

This proper forging technique will consolidate the central ingot metal and avoid internal bursts or tears. Tears are ruptures caused by pulling metal apart. Bursts are internal discontinuities caused by improper heating, cooling, or forging.

The operation must be performed in such a way that a satisfactory direction of flow lines will be developed, and the ingot axis maintained in a favorable relation to the final forging contours.

The ingot is taken to the Hydraulic Forging Press by an overhead crane. To make the forging solid, the ingot is there forged down and drawn out by repeated workings. The forging operation is discontinued when the ingot has cooled to about


GUN BARREL FORGING
TEST DISC
TEST DISC
36
67"
21' 5 1/2"
10

ITEM	NAME	NO PER UNIT	MATERIAL
	FORGING		STEEL

LIMITS, UNLESS OTHERWISE NOTED:
FRACTIONAL ± 1/64 DECIMAL ± .010 ANGULAR ± 1/2°

ENGINEERING DRAWING
AND DESCRIPTIVE GEOMETRY
GENERAL ENGINEERING DEPARTMENT
PURDUE UNIVERSITY
LAFAYETTE, INDIANA

TITLE OF UNIT: 5"/38 GUN BARREL FORGING
SCALE:
APPROVED:
TRACED BY:
CHECKED BY:
DATE: 1-12-1951
DRAWING NO: 2
DRAWN BY: DEL CASTILLO
CODE:

1800 degrees Fahrenheit.

The method used produces a forging whose length is considerably increased by reducing the section and simultaneously elongating the ingot. The working for reduction or shaping takes the form of a locally applied force which displaces the metal under compression, after which it is relieved and a new portion subjected to the working force.

The pressure exerted on the metal may vary from 1¼ to 25 tons per square inch. The slow application of pressure of the hydraulic press enables a relatively small press of 1,250 ton capacity to make forgings of a size that would require an enormous hammer, and results in deeper penetration.

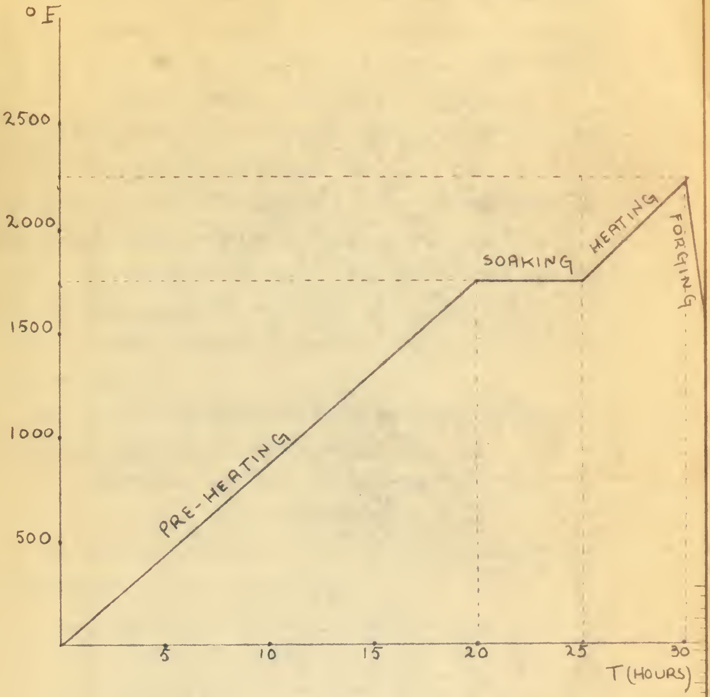
The forging process used in the National Forge is the following one:

a) The ingot is placed in the Ingot Heating Soaking Pit which is at a temperature of from 1800 to 2250 degrees Fahrenheit for approximately 28 hours.

The time for heating is about one hour per inch of diameter. The diameter of the ingot (Drawing No. 1) is 28-1/8".

b) After the ingot is heated to forging temperature it is removed from the Ingot Heating Soaking Pit and placed in the 1,250 ton forging press. The ingot is forged to a 19½" octagon. The forging operation is stopped when the temperature comes down below 1800 degrees Fahrenheit, and takes about one hour.

c) The 19½" octagon is placed in the reheat furnace and reheated to forging temperature for about 19 hours.



LIMITS, UNLESS OTHERWISE NOTED
FRACTIONAL ±1/64 DECIMAL ±.010 ANGULAR ±1/2°

	PRE-HEATING PROCESS		STEEL
ITEM	NAME	NO PER UNIT	MATERIAL

ENGINEERING DRAWING
AND DESCRIPTIVE GEOMETRY
GENERAL ENGINEERING DEPARTMENT
PURDUE UNIVERSITY
LAFAYETTE, INDIANA

TITLE OF UNIT: HEAT - TREATMENT

SCALE

APPROVED

TRACED BY

CHECKED BY

DATE 1-12-951

DRAWING NO 3

d) The $19\frac{1}{2}$" octagon is withdrawn from the reheat furnace, placed in the press, and forged to the sizes given on the final forging drawing. This second forging operation takes about 1.4 hours.

e) The gun barrel forging is buried in ashes for slow cooling for four days.

During the cooling period, the steel passes through a series of molecular changes effecting the structure of the metal. This change of structure produces internal stresses which must be controlled and minimized by slow cooling. The burying in ashes prevents air contact and permits uniform slow cooling.

The above represents a complete operation cycle.

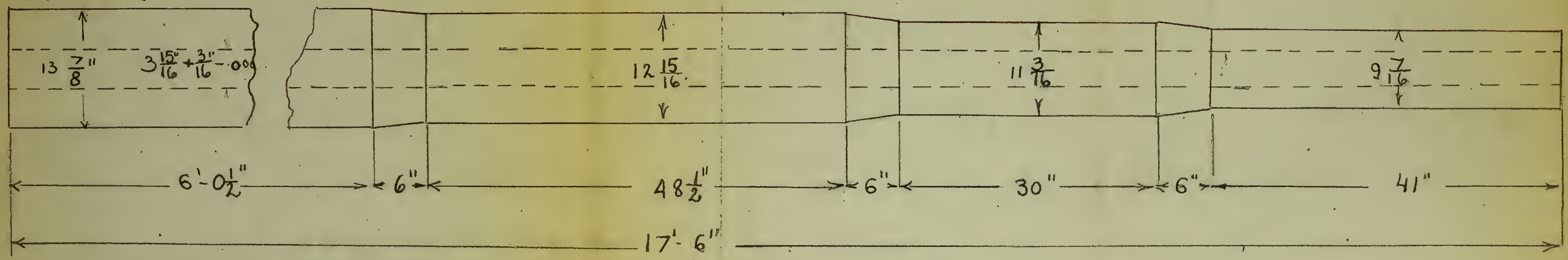
2-23- Manufacturing of the gun barrel.

Reference: a) Layout of the plant, Figure No. 1
b) Drawing No. 4.

In any industry the work to be done can be broken into the following types of activities:

1 - Imparting an original shape
2 - Changing the shape.
3 - Inspection.
4 - Assembly.
5 - Conversion.

In the manufacturing of the gun forging we imparted an original shape to the ingot already obtained. Now, in the manufacturing of the gun barrel we will change the shape of the forging by removing material. During the process we will


13 7/8"
3 15"/16 + 3"/16 − .000
12 15/16
11 3/16
9 7/16
6'-0 1/2"
6"
48 1/2"
6"
30"
6"
41"
17'-6"

LIMITS, UNLESS OTHERWISE NOTED:
FRACTIONAL ± 1/64 DECIMAL ± .010 ANGULAR ± 1/2°

	5"/38 GUN BARREL		STEEL ALLOY
ITEM	NAME	NO PER UNIT	MATERIAL

ENGINEERING DRAWING
AND DESCRIPTIVE GEOMETRY
GENERAL ENGINEERING DEPARTMENT
PURDUE UNIVERSITY
LAFAYETTE, INDIANA

TITLE OF UNIT: ROUGH TURN & ROUGH BORE
OUTSIDE DIA. ±.000 + 3"/16

SCALE:

APPROVED:

TRACED BY:

CHECKED BY:

DATE: 1-12-1951

DRAWING NO.:

DRAWN BY: DEL CASTILLO

CODE:

FORM DR 35A

see that we will make inspections, and by means of heating treatment, we will make conversions. Assembly will not be made because the gun barrel is an alloy steel monobloc.

A work unit is a modification of a product done without essential interruption. The work unit does not tell what machine or other equipment is to be used in order to modify the product. It only indicates what the modification will consist of.

These fundamental concepts will be the basis for the description of the manufacturing process.

Although the gun barrel forging is a product of impressive proportions, it frequently requires a machine finish comparable in accuracy with the fine parts of precision instruments. This requires machining craftsmanship of the highest order as well as equipment of exceptional size and capacity.

National Forge has organized its greatly extended machine shops with a multiplicity of machine tools divided into groups. The machining of such large products to such fine dimensions calls for skilled machinists in the machining of steel forgings.

The layout of the machine shop permits straight line production, the forging progressing in an orderly manner through its various machining operations: from cold sawing, rough machining, rough and finish boring, to finish turning, grinding, planing, slotting, drilling and milling.

A smooth system of crane operation carries the forging from one machine to another as the work progresses through the

main machining aisle of the machine shop.

A gun barrel steel forging is conceived in a blueprint and a set of specifications. Those specifications include a steel of specific analysis and heat treatment for certain desired physical properties, and precise tolerances for the finish machining.

The heat-treating schedule is the responsibility of the metallurgist and is checked by pyrometer controls.

A well equipped laboratory determines the physical properties by means of tensilic, impact and hardness tests.

Also available are X-ray and Magnaflux equipment to make sure that the exacting requirements are fully met in the final forging.

The micrometers and other measuring gauges used by the machine tool inspectors are checked against Johansson blocks.

The metallurgical laboratory is complete with equipment to make all kinds of examinations, such as macro-etch and microscopic inspection.

The physical laboratory is fully equipped for tensile, impact, and bend tests.

The machine shop is equipped with a wide range of tools for rough and finish machining. There are lathes for both turning and boring; from small bench lathes up to lathes of 72" swing and beds up to 120' long; boring machines; planers, both double frame and open side; radials drills up to 6'; surface grinders; cylindrical grinders for work up to 26" diameter and 50' long; shapers; milling machines; slotters,

up to 36" stroke; a jig borer; and a great many other machines and tools designed for special work.

DESCRIPTION OF THE PROCESS

Following the plant layout, we will describe the manufacturing process, summarizing the operations performed in each group of the machine shop.

First Operation: Center.

Machine - Horizontal centering machine.

Tool - Combined drill and countersink.

The gun barrel forging must be set up in the machines between centers, then it is necessary as a first operation to determine the centers. The center is determined in the horizontal centering machine, where the layout of the piece is done. The centers are obtained by means of a combined drill and countersink.

Second operation: Rough turn breech for a length of 24", spot for steady rest, face ends and open up for rough bore.

Machine - 36" x 35" Engine lathe.

Tools: a) High speed tool steel bit.
b) Drill.
c) Lathe bore tool.

The breech end of the forging is rough turned for a length of 24", in the 36" x 35" engine lathe. To spot for rough bore the diameter is smooth turned to receive the steady rest jaws

of the machine. The ends of the gun barrel forging are faced before the operation of rough bore. Open up is a preparatory work unit for rough bore. At first a drill is used and then a lathe boring tool.

Third operation: Rough bore.

Machine - 36" x 60' Boring Machine.

Tool - Rough bore tool on the boring bar.

The solid forging is placed on a boring machine and bored out as a preliminary operation for the next operation of boring.

Fourth operation: Rough turn.

Machine - 36" x 35' Engine Lathe.

Tool - High speed steel tool bit.

The outside diameter is rough turned as shown in Drawing No. 4. In this operation the speed is maintained as great as the tool will stand without requiring sharpening more often than every two or three hours when cutting continuously. As a rule, in this operation the greatest depth of cut and feed per revolution that the work, the machine and tool will stand at the highest practicable speed must be taken.

Fifth operation: Layout to drill end for heat treatment.

Bench work.

The bench leader carefully determines the positions of the holes to be drilled in order to avoid mistakes which might otherwise be made.

Sixth operation: Drill 4¼" hole.

Machine - Vertical drill.

Tool - Drill.

The 4¼" is drilled through the end at right angles to the axis of the forging on the vertical drill. This hole is used to attach the forging to the fixture so that it can be suspended in the Vertical Heat treating Furnaces.

Seventh, Eighth and Ninth operations: Heat-treatment.

Equipment - Vertical heat treatment furnace(5' diameter x 30' deep), and oil quench tank.

The heat-treating department is equipped with vertical furnaces and tanks for quenching. This equipment is available to normalize, quench and draw the gun barrel. This heat treatment is a necessary part of steel forging specifications for guns. Forgings suspended in these furnaces are free from external stresses. The oil firing applies heat evenly over the entire length of the forgings. This uniform heating avoids the development of internal strains. Quenching in a vertical position permits uniform cooling which further avoids the setting up of uneven strains in the forging.

Before heat treatment, as was done in previous operations, the gun barrel is rough machined to approximate size and shape so that the heat treatment will penetrate uniformly over its entire surface area.

The elements of time and temperature of heating are extremely important. To make sure that each forging receives its prescribed heat treatment, recording pyrometers are used, to register a chronological record of temperatures throughout the heat treating cycle. The length of time that a forging remains in a furnace depends of the size forging, its carbon

content, and the temperature of the furnace.

The oil quenching tanks, 5' in diameter and 30' deep, into which the forging is immediately immersed after removal from the furnace, are about the same size as the heating pits, and are also sunk in the ground.

Forgings are immersed in the direction of their longitudinal axis. The oil is kept in circulation continually by means of a pump which forces it up through the bottom of the tank,the overflow being carried off by a pipe at the top to a tank outside the building. The quenching treatment is obtained by immersion in the oil.

In the normalizing treatment, the iron-base alloy is heated to approximately 100 degrees F. above the transformation temperature range followed by cooling to below that range in air at room temperature.

In the drawing treatment the alloy steel is heated below the transformatian temperature range followed by the desired rate of cooling inside the furnace. When cooled to about 300 degrees F., the forging is removed from the furnace.

The transformation temperature range is the temperature spread within which the atomic, molecular or granular structures of iron-base metals change their forms.

Tenth Operation: Saw

Machine - Saw

Tool - Circular saw.

The test specimens are cut from the ends in locations specified and pulled to determine if the alloy steel will meet the physical requirements. The factory has a well

equipped testing laboratory where accurate determinations are made of the physical properties of the heat treated forgings. These tests include tensile, impact, and hardness tests. Specifications governing the manufacture of ordnance material, which are changed from time to time to keep up to date with the best metallurgical practices and results, state the physical requirements the material must fulfill. These requirements are carefully checked by inspection and analysis in the testing machines.

Eleventh operation: Indicate and mark runout.

Equipment - Indicator.

If the"indicating and mark run out" operation shows that the gun barrel warped, it is heated to a point below drawing temperature and straightened.

To straighten the gun barrel a press similar to the one used to forge the ingotis used.

Twelfth operation: Spot, face and open up for first hognose.

Machine - 36" x 35' Engine lathe.

Tool - High speed tool steel bit.
Lathe boring tool.

The gun barrel is smooth turned to receive the steady rest jaws of the boring machine. The ends are faced. To prepare for the work unit "hognose", the gun barrel is opened up using a lathe-boring tool.

Thirteenth Operation: First hognose.

Machine - 26" x 60' Boring machine.

Tool - Packed bit (hognose shape).

The packed bit consists of a cylinder of maple built on a steel frame. The two cutters used in obtaining the hognose shape, diametrically opposite, are set in a frame at its forward edge to the size of the hole it is intended to bore. The diameter of the wood packing is maintained a few thousandths greater than the diameter of the cutters so that the close fit in the bore will furnish a steady bearing for the cutters. The shank of the bit is secured to a boring bar by means of a threaded section. The packed bit boring bar is a long bar which is supported in several bearings and which is driven longitudinally by a motor drive.

Fourteenth Operation: Indicate and mark runout.

Equipment - Indicator.

To ascertain whether a bore has been done true, it is indicated for eccentricity. A dial is mounted on the end of a long telescopic pipe placed in the bore. As the forging is revolved over the rollers on the V blocks, the eccentricities of the bore, pressing against a spring-loaded arm, cause a hand on the face of the dial to rotate in either direction. This gives plus or minus readings in thousandths of an inch.

Fifteenth Operation: Rough turn outside diameter to plus 3/16" over finish size, spot, face, and open up for second hognose.

Machine - 36" x 35' Engine lathe.

Tool - High speed steel tool bit.

Lathe boring tool.

The outside diameter is rough turned in two cuts to plus

3/16" over finish size. The machine used is a rough engine lathe with a 30 H.P. drive motor. The other operations are preparatory to the second hognose.

Sixteenth Operation: Second hognose.

Machine - Boring machine.

Tool - Packed bit.

A second rough bore with a packed bit is made, bringing the bore diameter to 4.65".

Seventeenth Operation: Indicate and mark runout.

Equipment - Indicator.

The procedure is the same as the Fourteenth Operation.

Eighteenth Operation: Radial expansion.

Equipment - a) Intensifier.
b) Connections.
c) Arbor.
d) Packings.
e) Screwed-in-plugs.
f) Gauge.

By the radial expansion, hydrostatic pressure is applied to the bore until the outer surface is stressed to approximately its elastic limit, as prescribed on the specifications and technical instructions.

The forgings are expanded in separate pressure stages, beginning with the breech state and progressing in sequence toward the muzzle. During each application of the prescribed pressure the portion of the bore from the packing at the breech end to the forward limit of any pressure stage is sub-

jected to the bore pressure prescribed for that stage.

The apparatus for radially expanding gun forgings consists of pumps, an intensifier and arbor connected by high pressure piping and provided with check and drain valves, and gauges for measuring the pressures. The intensifier serves to step up the hydrostatic pressure to a maximum of 125,000 lb. per sq. inch. The arbor which is inserted in the bore of the forging carries the longitudinal load due to the packings and acts as a filler bar by means of which the liquid necessary to expand the gun forging is reduced to a thin amount between the arbor and the bore of the forging.

Packing at each end of the bore is held in position by screwed-in plugs to seal the liquid under pressure. The pressure is applied in increments of 5,000 lb. per square inch. Characteristics of the stages of expansion:

Stage	Maximum Pressure	Theoretical dilation	Increments of Pressure	Measuring Stations
First	79,210 lb/sq/in.	0".0285	5,000 lb/sq/in.	1,2,3,4
Second	72,980 lb/sq/in.	0".0265	5,000 lb/sq/in.	5,6,7,8
Third	59,910	0".0228	5,000 lb/sq/in.	9,10,11
Fourth	45,200 lb/sq/in.	0".0190	5,000 lb/sq.in.	12,13,14

As the pressure is applied in increments of 5,000 lb/sq/in., the outside diameters are measured and checked against

a theoretical curve showing the relation between the bore pressure and the dilation of the outside diameter.

Ninteenth Operation: Inspection.

Equipment - Indicator.

After the radial expansion operation the gun barrel is set up in a bench over V blocks with rollers to determine its inside and outside runout. The maximum runout permitted for 5"/38 gun forging is 0.20". If the runout exceeds this amount the forging is straightened at shop temperature, provided that the height of the bow or arc does not exceed .004" per inch of length over which the arc extends. After such straightening the runout of the forging should not exceed .20".

Twentieth Operation: Finish bore.

Machine - Boring Machine.

Tool - Packed bit.

The gun barrel is then finish bored with a 5 inch hole straight through. Two cuts are required. The allowed tolerance is only 0.002" oversize and zero undersize. 0.005" is allowed for honing.

Twenty-first Operation: Indicate.

Equipment - Indicator.

The same procedure is used as in Operation Fourteen.

Twenty-second Operation: Honing.

In a combined movement of rotation and translation, a head with several stone segments held out against the bore by springs gives a final finish and polishing known as honing. A special machine is used.

Twenty-third Operation: Finish turn, file and polish, and cut out threads.

Machine - 36" x 35' Engine lathe.

Tool - Broad nose tool.

The gun barrel is finished on the outside diameter to the prescribed dimensions. This operation must be done before rifling. The tolerance specified is usually within 0.001 inch. Snap gauges are used to check the dimensions.

The external file and polish treatment is given by special cleaning and polishing devices which are held by the workers while the gun barrel is rotating in the lathe.

The threads are cut on the outside of the barrel.

Twenty-fourth Operation: Rifling.

Machine - 5"x45' Rifling machine.

Tool - White rifling head, and grooved bar.

The gun barrel is rifled, using a white rifling head and a grooved bar. The groove in the bar corresponds to one turn in 30 calibers.

The rifling head has 3 sets of cutters. The first set is used to cut the grooves to the full depth by taking from a half-thousandth to a thousandth of an inch per cut. The second set and the third set are used to widen out the grooves to the proper width.

The rifling operation is very long. It takes 60 hours. Rifling is done in a machine resembling a boring machine, except that the rifling bar, which takes the place of the boring bar, has a spiral slot cut in its surface, the pitch of which

corresponds to the pitch of the rifling it is desired to cut. A different bar, then, is required for each type of gun.

An extension of the bed plate alongside the rifling bar carries a steel spline, which is set to the form of the developed rifling by set-screws. For rifling of uniform twist the development is a straight line. For increasing twist the development is a curve. By means of the spline, the pinion gearing, and the rack, one end of which is kept pressed against the spline, the rifling bar is revolved at the proper rate as it is fed past the stationary cutting tool.

The white rifling head, a hollow cylinder slightly smaller than the bore of the gun, is keyed in a socket in the end of the rifling bar. The cutting tools are set in pockets placed at equal intervals circumferentially around the forward edge of the head. The number of tools is half the number of grooves to be cut.

A cone, which is moved axially inside the head by a screw, is employed to move the tools outward. The screw, which has a vernier to indicate the position of the cutting tools, is reached through an opening in the side of the head.

A pin projecting through the front face of the head, when pushed in, causes the cutters to collapse inward, thus enabling the head to be withdrawn without danger of scoring the bore.

All rifling is done from the muzzle end. When the bar is advanced for the first cut, a lug in the forward steady rest bearing engages in the rifling bar slot and rotates the bar as the head is fed into the gun, cutting the grooves with the

correct pitch. After rifling, the lands and grooves are star-gauged. The action of the cutting fluid for lubricating and cooling the cutters is very important.

Twenty-fifth Operation: Bore out chamber.

Machine tool - 36" x 35' Engine lathe.

Tool - High speed tool steel bit in a boring bar. A profile is used to trace the contour of the chamber.

The engine lathe is used for boring out the chamber.

There are two general designs for the powder chamber, those for bag guns and those for cartridge case guns. This example is the latter and is much simpler to bore. The chamber is checked by fitting in a gauge made to the maximum dimensions allowed for the cartridge case.

Twenty-sixth Operation: Grind chamber.

Machine - Internal grinder.

Tool - Grinding wheel (cylindrical) and a profile used to trace the contour of the chamber.

The internal grinder is used for grinding the chamber. The grinding wheel is mounted on a slide parallel to the ways of the machine. The movement of the tool is rotary and reciprocating. The feed is perpendicular to axis of the work.

Twenty-seventh Operation: Extractor slots.

Machine - Planer.

Tool - End mill.

The extractor slots are milled in the breech end to a layout done on the face of the breech end.

Twenty-eighth Operation: Key way.

Machine - Planer.

Tool - Milling cutter.

The key way is cut in the outside of the barrel. The purpose of the key is to keep the gun barrel from turning on its slide. This milling operation is done in the planer.

Twenty-ninth Operation: Interrupt thread.

Machine - Planer.

Tool - Milling cutter.

This operation is done in the planer, with the tool stationary and the work reciprocating. The capacity of this planer is 36"x36"x14".

Thirtieth Operation: Chrome plating.

Equipment - Electroplating tank.

This process is used to chrome plate the bore of the gun barrel. With the advent of chrome plating many opportunities developed for increasing the life and usefulness of ordnance parts by electroplating areas where excessive wear occurred. Chromium, being hard, of considerable wear resistance, and of some corrosion resistance, gave increased life to parts such as the gun barrel which are subjected to these conditions. All major caliber gun barrels from 3" to 16" are chromium plated throughout the bore.

b)

Plant Equipment

Once the basic manufacturing process has been determined, the next step is to select the productive equipment along with its standard and special tools, jigs, fixtures, etc...

By means of the forging process an original shape was imparted to the gun barrel forging. The reduction of material to specified shape and dimensions was obtained by the action of cutting tools and machinery. The heat-treating department, by normalizing, quenching, and drawing the gun barrel, changed the physical properties of the metal in accordance with specifications. In the radial expansion process the bore and the external diameters were slightly enlarged because of the permanent deformations set up by the hydrostatic pressure.

This step will be the selection of the exact type of productive equipment required to perform the outlined process, and the calculation of the number of machines necessary. To do this we will make use of production data. The first item of information to be utilized is a forecast of the production required. This is essential to an appraisal of the production equipment required.

The primary objective in selecting the exact number of machines is the prevention of bottleneck operations. The estimated production is:

a) Units per year - 950 gun barrels.

b) Plant capacity in units per day - 4 gun barrels.

Next to be considered is the work-shift policy.

Based on this policy, the number of hours that the equipment is to operate per week can be computed. The length of the working day will be considered, as well as the number of shifts. This factory is a continuous-process industry, where because of "warm up" cost, the 24-hour day is a virtual economic necessity.

There are two major factors which will combine to reduce the established production rate:

a) Loss through scrap or rejects.

b) Low production efficiency.

In this factory, due to the high price of the gun barrel forging, (about $2,700.00 per piece), the loss through scrap or rejects has been reduced to a minimum. We will assume that this figure is so small that this allowance will not be taken into consideration. The important factor is the production efficiency.

We will selectthe types of machine tools and the number required for each of the following groups of the machine shop:

1) Rough Machine.

2) Finish Machine.

3) Heat Treat.

4) Press.

5) Melting.

DATA FOR COMPUTATION

1) For: Rough turn, rough bore, finish turn, finish turn, finish bore, grind, plane, honing, and radial expansion.

    a) hours/day = 24
    b) days/week = 6
    c) weeks/year = 50
    d) hours/year = 24x6x50 = 7,200
    e) good units/year = 950
    f) good units/hour = $\frac{950}{7,200} = 0.132$
    g) production efficiency = 80% (data given by the chief engineer).

2) For: Drill and saw.

    a) hours/day = 8
    b) days/week = 5
    c) weeks/year = 50
    d) hours/year = 8x5x50 = 2,000
    e) good units/year = 950
    f) good units/hour = $\frac{950}{2000} = 0.475$
    g) production efficiency = 80%

3) For rifling.

    a) hours/day = 24
    b) days/week = 7
    c) weeks/year = 50
    d) hours/year = 24x7x50 = 8400 hours/year
    e) good units/year = 950

f) good units/hour $= \frac{950}{8,400} = 0.114$

g) production efficiency $=$ 80%

FORMULA FOR COMPUTATION [1]

$$N = \frac{\text{Number of good units per hour.}}{\frac{1}{\text{Standard time}} \text{ x Plant efficiency}}$$

COMPUTATION

Rough Machine Group

1) Boring machines (rough bore)

Standard time for the operation = 16 hours

$$N = \frac{0.132}{\frac{1}{16} \text{x} .80} = 2.7 = 3 \text{ machines.}$$

2) Engine lathes (rough turn)

Standard time for the operation - 14 hours

$$N = \frac{0.132}{\frac{1}{14} \text{ x } .80} = 2.3 = 2 \text{ machines.}$$

3) Vertical drill

Standard time for the operation: 2.5 hours

$$N = \frac{0.475}{\frac{1}{2.5} \text{ x } .80} = 1 \text{ machine}$$

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1. Apple, J.M., "Plant Layout and Materials Handling", The Ronald Press Co., New York.

Finish Machine Group

1) Boring Machine (finish bore)

Standard time for the operation: 21 hours

$$N = \frac{0.132}{\frac{1}{21} \times .80} = 3.5 = 4 \text{ machines}$$

2) Engine lathes (finish turn)

Standard time for the operation: 32 hours.

$$N = \frac{0.132}{\frac{1}{32} \times .80} = 5.3 = 5 \text{ machines}$$

3) Planers

Standard time for the operation: 20 hours

$$N = \frac{0.132}{\frac{1}{20} \times .80} = 3.3 = 3 \text{ machines}$$

4) Internal grinders

Standard time for the operations: 15 hours

$$N = \frac{0.132}{\frac{1}{15} \times .80} = 2.4 = 2 \text{ machines}$$

5) Honing machines

Standard time for the operation: 15 hours

$$N = \frac{0.132}{\frac{1}{15} \times .80} = 2.4 = 2 \text{ machines}$$

6) Rifling machines

Standard time for the operation: 60 hours

$$N = \frac{0.114}{\frac{1}{60} \times .80} = 8 \text{ machines}$$

Summary of Equipment

1 - Melting Shop:	
1-1 - Electric melting furnace, capacity 15	1
1-2 - 10 ton scale	1
1-3 - Furnace transformer	1
1-4 - Pouring Pit	1
1-5 - Ingot Heating Soaking Pit	6
1-6 - Reheat furnaces (two chambers)	2
1-7 - Chemical laboratory	1
1-8 - Electrical sub-station	1
2 - Forge Shop:	
2-1 - 1250 High Speed Steam Hydraulic Forging Press	1
2-2 - Straight line manipulator (10,000 lb.).	1
2-3 - Boilers (150 p.s.i., 5,000 lb/h)	2
2-4 - Water Softener	2
2-5 - Steam feed water pump	2
2-6 - Saws	2
3 - Machine Shop:	
3-1 - Rough Machine Group.	
3-11 - Boring Machines (rough bore), 36" x 60'	3
3-12 - Engine lathes(rough turn),36"x35'.	2
3-13 - Vertical Drill	1
3-14 - Bench (layout to drill).	1

3-2 -	Finish Machine Group:	
3-21 -	Boring Machines (finish bore), 36" x 60'	4
3-22 -	Engine lathes (finish turn),36"x35'	5
3-23 -	Planers, 36"x36'x14'	3
3-24 -	Internal grinders	2
3-25 -	Honing machines	2
3-26 -	Rifling machines, 5"x45'	8
3-3 -	Heating Department:	
3-31 -	Vertical furnaces 5' dia.x 30'deep.	4
3-32 -	Oil quenching tank 5' dia.x30'deep.	1
3-33 -	Water quenching tank 5'dia.x30'deep	1
3-4 -	Radial Expansion:	
3-41 -	Indicating benches	2
3-42 -	Rough engine lathes	2
3-43 -	Radial expansion equipment	2

c)

Layout of the Plant

Reference: Plant layout - Drawing No. 5.

The machine tools are laid out by the product-line method, in the order in which they are used.

The flow of materials is in the form of a U so that production progresses from one point to another.

This arrangement of equipment speeds up the manufacturing cycle by reducing the inventory of pieces in process as well as the time required for their handling, makes production easier to control, and eliminates back tracking of materials.

III - PAPER WORK INVOLVED IN THE PRODUCTION PLANNING OF THE NATIONAL FORGE & ORDNANCE COMPANY

a)

Standard Process Sheet

Reference: Figure No. 2

By definition, production planning is the procedure for drawing a complete process sheet, starting from a description of the product to be made and a knowledge of the approximate volume required. A process sheet is a special form of a process-chart product-analysis.

Based on the above considerations we can say that a process sheet is the analysis of the separable steps of the procedure involved in performing the work required to modify a product. This analysis is indispensable prior to the starting of production as an aid in obtaining the best possible process and in developing standard procedures.

In the National Forge & Ordnance the "Standard Process Sheet" is known by the code: Form No.12 9-45 3000N. It should be noted that this form is set up in order to obtain a logical and definite sequence of operations performed on a certain product at a definite time. The body of the sheet consists of:

First column: Operation number.

To indicate the sequence of operations, each one receives a number. The first operation receives the number 10, the second 20, etc.... This is done because sometimes the study of the process indicates the need for a new operation between

-45 3000N

61a

CUST. ORDER ____ CUSTOMER ____

ER ____ PROMISED Mar 29, 1951 STEEL Alloy Steel

S. 4/day DESCRIPTION Gun Barrel TREATMENT Normalize-Quench-Draw

NAME OF OPERATION	MCH. NO.	ESTIMATED TIME (Hours)
Center	HC1	.5
Rough turn breech, spot, face ends and open up	EL 1	7.5
Rough Bore	BM1	16.0
Rough turn	EL2	14.0
Layout to drill	B1	.4
Drill 4¼" hole	D1	2.5
Heat-treat (Normalize)	H-T-1	8.0
Heat-treat (Quench)	Q-T-1	8.0
Heat-treat (Draw)	H-T-2	8.0
Saw ends	C-S-1	1.7
Indicate and mark runout	I-1	2.5
Spot, face and open up for first hognose	E L 3	8.5
First hognose	B M 4	14.0
Indicate and mark runout	I-2	2.5
Rough turn outside diameter to plus 3/16" over/finish	EL 4	14.0
Second Hognose	BM 5	14.0
Indicate and mark runout	I-2	2.5
Radial Expansion	AF 1	14.0
Inspection	I-2	2.5
Finish bore	BM 6	21.0
Indicate and mark runout	I-2	2.5
Honing	H 1	15.0
Finish turn, file, polish, and cutout threads	EL 5	32.0
Rifling machine	R 1	60.0
Bore out chamber	EL 6	25.0
Grind chamber	G 1	15.0
Mill Extractor slots	P 1	14.0
Cut key-way	P 1	3.0
Interrupt thread	P 1	3.0
Chrome plate	CP	-

two operations which were numbered before. In this case the new operation can receive the number 11 and all other operations in the sequence will keep the previous numbers. The numbers in this column indicate the sequence of operations.

Second Column: Name of Operation.

It states the operations necessary to manufacture the article or part in their proper sequence. The work units are listed within each operation in the order required by the process. Here it is necessary to establish a clear distinction between "operation" and "work unit." An operation is a modification of a product that takes place essentially at one location. A "work unit" is a modification of a product done without essential interruption.

Third Column: Machine number.

This column is used to indicate the machine tool where such operations will be done and the equipment which will be used. After grouping the work units into operations and arranging the operations in the proper sequence, we now determine the equipment needed to perform the work.

This factory has the following groups, roughing machines, finishing machines, heat-treatment, radial expansion, and rifling. Inspection is under the material control department and the laboratories are under the quality control section.

Fourth Column: Estimated time.

The standard time is set operation by operation.

In the manufacturing of gun barrels, the standard times are obtained from existing data. If some alteration takes

place in the process or in the equipment the standard time is again determined from time studies, improved procedures, and work simplification studies performed by the "Production Planning Department" of the Engineering Division.

The set-up time is included in the standard time for each operation. In this factory the set-up of the machine is made by the operator and the time involved in setting up is very small, compared with the length of time of the operation.

Heading of the form:

The heading of the form contains:

a) Code
b) Number of customer order.
c) Name of the customer.
d) Number of the shop order.
e) Number of pieces to be manufactured.
f) Description or piece name.
g) Treatment to be made.

Estimate Sheet

Reference: Figure No. 3

After preparing the "Standard Process Sheet", production planning prepares the "Estimate Sheet".

The columns "Operations" and "Hours" are taken from the columns "Name of Operation" and "Estimated Time" of the "Standard Process Sheet".

The new columns in this sheet are:

ESTIMATE SHEET

N F & O Co. Form 264

Comparisons

Operations	Hours	Rate	Cost		Check	

Inquiry from No. Pcs. Dwg. No.

Treatment

Tests

a) Rate.

b) Cost.

c) Check.

The rate is based on the estimated manufacturing costs. It is an accepted practice when estimating costs of products to divide the cost into three main divisions:

a) Labor.

b) Material.

c) Overhead.

In this company, because of long experience in this kind of manufacturing, the engineering department knows the values of the rates of the divisions above, and therefore the combined rate which must be filled in the third column of the "Estimate Sheet".

The engineering department knows, based on the experiance, that:

a) The rate of the forging press, including the furnaces and the manipulator, is $125.00 per hour.

b) The rate of the heat-treat furnaces, including the tanks, is $80.00 per hour.

c) The rates on the saw, centering machine, and vertical drill are $8.00 per hour.

d) The rates on the engine lathes (rough and finish), boring machines (rough and finish), rifling machines, planers, internal grinders, and honing machines are $10.00 per hour.

The fourth column will give the price of each operation,

based on the figures in Column 2 (hours of operation) and Column 3 (rate/hour of each machine involved in the operation).

A considerable amount of time is saved by making use of previously estimated parts which are components of the product, or of the product itself as in our case, on which an estimated cost is desired. The estimated costs computed in Column 3 are compared and checked against Column 4 (check). In Column 4 we have the complete cost of the operations, as computed by the accounting department of the financial division, where consideration has been given to changes in labor rates, material costs, plant equipment, transportation facilities, maintenance, and the expected depreciation of the assets.

In the lower part of the "Estimate Sheet", the form contains:

a) Shipping weight.
b) Freight rate.
c) Tool expense.
d) Date.
e) Number of pieces.
f) Drawing number.
g) Name or description of the piece.
h) Specifications.
i) Physicals.
j) Treatment.
k) Exceptions.
l) Test.

m) Price.

n) Shipment date.

b)

Process chart - Product Analysis

Reference: Figure No. 4

"A Process Chart-Product Analysis is a graphic means of portraying the separable steps of the procedure involved in performing the work required to modify a product from one stage of completion to another. Process-Charts-Product Analysis should be made whenever possible for all materials, prior to the inception of production, to aid in obtaining the best possible process and layout before the beginning of work."[1]

The Process Chart - Product Analysis annexed to this thesis illustrates the manufacturing procedure for the gun barrel that is used in the National Forge & Ordnance Company.

c)

Operator Instruction Sheet

Reference: Figure No. 5

The results of operation study are recorded on such forms for the instruction of foremen and operators. The standard process sheet determines the processes and time allowances for each operation.

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1. Mundel, M.E., "Motion and Time Study Principles and Practices", New York, Prentice Hall, 1950.

pe of Chart PROCESS CHART - PRODUCT ANALYSIS

Method ORIGINAL Machine No.

Operation MANUFACTURE OF COMPLETED PART Operation No.

Part No. 101

art name GUN BARREL Chart by DEL CASTILLO

perator– Date charted MARCH-20-1[illegible]

	SYMBOL	EXPLANATION
	◯	First heat to forge
	○	To forge
	◯	Forge (1,250 ton. hrd. press)
	○	To second heat
	◯	Second heat to forge
	○	To forge
	◯	Forge to final sizes
	○	To Bury in ashes
	◯	Buried in ashes
	◯	Cool
	◯	Dug up
	○	To saw
	◯	Saw ends and saw micro discs
nds and discs ○	○	To rough industrial truck
o lab. ▼	◯	On the industrial truck
	○	To machine shop
	□	Quantity inspection
	○	To receiving department
	▽	Controlled storage at receiving
	○	To quality inspection
	◇	Quality inspection against micro discs
	○	To rough department
	▽	Temporary storage at rough department
	○	To horizontal centering machine
	◯	Center

pe of Chart PROCESS CHART-PRODUCT ANALYSIS

Method ORIGINAL Machine No.

Operation MANUFACTURE OF COMPLETED PART Operation No.

Part No. 101

art name GUN BARREL Chart by DEL CASTILLO

perator Date charted MARCH-20-1951

SYMBOL	EXPLANATION
○	To engine lathe
◯	Rough turn breech-spot-face ends-open up
○	To rough bore
◯	Rough bore
○	To engine lathe
◯	Rough turn
○	To drill
◯	Layout to drill
○	To vertical drill
◯	Drill $4\frac{1}{4}$ hole
○	To heat -treatment
◯	Heat- treatment (normalized)
○	To quench
◯	Quench
○	To draw
◯	Drawn
○	To saw
◯	Cut test specimens
○ ○	To inspection
↓ ◇	Indicate and mark run out
Test specimens ○	To engine lathe
to metallurgical ◯	Spot- face- open up
laboratory ○	To first hognose
◯	First hognose
○	To inspection

pe of Chart PROCESS CHART - PROCESS ANALYSIS

Method ORIGINAL
Machine No.

Operation MANUFACTURE OF COMPLETED PART
Operation No.

Part No. 101

art name GUN BARREL
Chart by DEL CASTILLO

perator–
Date charted MARCH-20-1951

SYMBOL	EXPLANATION
◇	Indicate and mark runout
○	To engine lathe
◯	Rough turn-spot-face-open up
○	To second hognose
◯	Second hognose
○	To inspection
◇	Indicate and mark runout
○	To radial expansion
◯	Radial expansion
○	To inspection
◇	Inspection
○	To finish bore
◯	Finish bore
○	To inspection
◇	Indicate and mark runout
○	To honing
◯	Honing
○	To engine lathe
◯	Finish turn, file, polish, cut threads
○	To rifle
◯	Rifling
○	To engine lathe
◯	Bore out chamber
○	To grind
◯	Grind chamber

If more space is needed paste additional sheet on here.

ype of Chart PROCESS CHART - PRODUCT ANALYSIS

Method ORIGINAL
Machine No.

Operation MANUFACTURE OF COMPLETED PART
Operation No. 101

Part No.

art name GUN BARREL
Chart by DEL CASTILLO

perator-
Date charted MARCH-20-1951

SYMBOL	EXPLANATION
○	To planer n° 1
◯	Machine extractor slots
○	To planer n° 2
◯	Machine key way
○	To planer n° 3
◯	Interrupt threads
○	To chromium plate
◯	Cromium plate
○	To shipping department
□	Quantity inspection
▽	Controlled storage at shipping department

SYMBOLS	NAME	QUANTITY
◯	OPERATION	34
□	QUANTITY INSPECTION	2
◇	QUALITY INSPECTION	6
○	MOVEMENT	42
⛛	TEMPORARY STORAGE	1
▽	CONTROLLED STORAGE	2

In the "Operator Instruction Sheet", details of the particular operation are written, and the operators are expected to follow the planned method until a change is authorized. In the "Operator Instruction Sheet" information is given concerning:

a) Sketches for the piece to be forged.

b) Standard time for one piece.

c) Name of operation.

d) Number of pieces.

e) Steel alloy necessary for the operation.

f) Heat-Treatment required.

g) Dimensions of the piece.

h) Weight of the steel required.

i) Net weight of the forging.

j) Customer order number.

In other cases, as in the machining of one piece, the tool layout is sketched, and informations about cutting speed in r.p.m. or ft./min. and feed in inches per revolution are placed in the sheet.

These sheets, when they are necessary, are sent with the standard process-sheet to the forman of the department.

The time-keeper of the department places the "standard time" in the operator instruction sheet and he records the time when the operator starts the operation.

In this factory this sheet is used to help the worker on any operation of the manufacturing process. It is used for the work of individuals, as on the lathes, boring machines,

[illegible]	PROMISED	CUST. ORDER	[illegible]	ROUGH WT
			STEEL	FINISH WT
				NET WT
	TREATMENT			[illegible]

CH. STANDARD TIME FOR OPERATION

ACTUAL TIME FOR OPERATION

etc, and also on the work of crews, as in the case of the forging operation. Another characteristic of this sheet in this particular plant is that it is used as a Time Record. The time keeper has on his sheet the time allowed for the operation and records the time actually spent on the job. The time spent can then be compared with the time originally estimated.

These work records of the "operator instruction sheet" are compared with the records of the clock cards for cost accounting and payroll purposes. From these records the payment of special premiums, bonus and overtime is calculated.

SECTION TWO

ANALYSIS OF THE UNITED STATES NAVAL GUN FACTORY

1. History.

"In 1799, when the Washington Navy Yard came into being as the production and maintenance arm of a young United States Navy, it had a long and challenging row to how. French depradations on American shipping and an undeclared war with Tripoli, which had been responsible for bringing the Yard into being, preceded its baptism of fire.

"During the War of 1812, the burning of Washington by the British forced the Secretary of the Navy to order the torch put to the Yard to prevent its stores and powder from falling into the hands of the enemy. It was a grim order that Captain Thomas Tingey, the first Commandant of the Navy Yard, was obliged to carry out, and it was not until the end of 1814 that the work of reconstruction could begin.

"However, by 1816 there had risen from the blackened twelve acres of land three large brick storehouses, a work shop 1900 feet long, a forge house with twenty-two forges and three furnaces, a steam-operated forge hammer, three ship houses and ways, timber yards and wharfs. Even in this early period of its growth, the Navy Yard had become a major source of new materials, the scene of the evolution of many ordnance manufacturing processes and of the development of skilled artisans.

"Because the Anacostia River tended to fill its bed, the Navy Yard gradually became armorer to the fleet rather than shipyard, but development work continued, nevertheless, in hull and machinery improvement.

"An iron steamer, the Waterwitch, was built in 1843, and when the Merrimac, one of the "ironsides," struck at Newport News after the outbreak of the Civil War, the Yard workers were prepared to accelerate the counter-development of armor plate, a function which grew to tremendous importance then and as time went on.

"During this war period, the Navy Yard was the base from which the Potomac Flotilla operated to keep that strategic line of communications open to the sea; ordnance production was expanded and the Yard personnel, naval and civilian, assisted gallantly in the defense of the Capital. From its founding, it had served the nation as faithfully as it was to do through three more wars.

"In 1883, when construction of the new American navy was begun, it fell to the Yard to supply guns, gun mounts, ammunition hoists, shells and torpedo tubes to the fleet. So the establishment was prepared for the later task, on the outbreak of war with Spain, to overhaul and transfer the stock of slow fire guns to what was known as "quick-fire" guns - a change from percussion to electric firing. Work was rushed to complete this equipment for Commodore Watson's squadron that was to carry the war into Spanish waters, but the brevity of the conflict did not permit the factory to deliver the new

ordnance, and fighting was done with the equipment on board at the beginning of the war, all of it produced at the Navy Yard in preceding years - a performance that proved a job well done.

"With the election of Theodore Roosevelt to the Presidency, the ordnance factory of the Yard operated on a round-the-clock schedule to meet the extensive expansion program for the enlarged fleet. Many improvements in plant and equipment were made to permit, among other things, the handling and assembling of from 1" to 16" guns.

"Except for a brief return to the normal work load during the Taft administration, development continued on a twenty-four hour basis through World War I, when orders for 14", 50 caliber guns, experimental batteries of 18" guns for battleships, fire control systems, firing circuits, lighting systems and wireless equipment drove the Yard to the limit of its production. The most outstanding performance was the rapid design and completion of the naval railway guns intended for long-distance bombardment of enemy lines after the German invasion of France.

"The Yard was naturally affected by the disarmament program that followed the war, but the naval building program, initiated by President Franklin Roosevelt, began another period of great expansion that led eventually to the extraordinary volume of ordnance production during World War II. All records for naval weapon development and manufacture were exploded by the huge tonnage of complex material that came

from the factory, much of it far ahead of ship installation schedules, while design and development of experimental models of new weapons of war continued.

"Today, a visitor to the Naval Gun Factory - as it was renamed in 1945 - might consider the name a misnomer. For in the 188 buildings that sprawl over 125 acres along the Anacostia River and have become the primary industrial establishment of the District of Columbia, and the largest naval armament plant in the world, there are facilities for the research and development of aircraft armament, the production of optical instruments, rockets and rocket launchers, bomb and torpedo equipment, depth-charge projectors, electrical and electronic equipment and myriad miscellaneous special weapons, apart from the manufacture of guns, fire control equipment, and catapult guns. In fact, the Gun Factory which produces the finest naval ordnance in the world, is a master factory and a center of mechanical and manufacturing efficiency such as industry rarely sees." [1]

"The first real step in the conversion of the Yard into an ordnance plant was taken on August 16, 1847, when the Bureau of Ordnance placed Lieutenant John A. Dahlgren, U.S.N., at the head of an independent department and gave him the direction of all ordnance matters at the Navy Yard. A further concentration upon ordnance manufacture came as result

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1. Public Information Office, "Ordnance Production", Washington, D.C., U.S. Naval Gun Factory, 1951.

of the general order of August 14, 1886, which established the Gun Factory at the Yard. The principal growth of the Gun Factory took place during those years when the defense of the nation demanded the utmost in the design and production of naval ordnance. The unique character of the establishment was officially recognized when the Washington Navy Yard became the U.S. Naval Gun Factory on December 1, 1945. This was a simple change in title and not in function.

"During both World Wars the Naval Gun Factory has been the master technician and inspector for the nation-wide system which the Bureau of Ordnance established for the production of naval weapons. Taking original design and research data from other agencies of the Bureau, the Naval Gun Factory has made and continues to make prototype models of weapons for experiment and testing. Its singular success in this field may be attributed in no small measure to the accumulated experience and skill of its designers and mechanics, many of whom have several decades of service to their credit. The attributes of a long-practice trade combine with sound training to make versatile and reliable craftsmen. The history of the Washington Navy Yard and the Naval Gun Factory is a double history. It is the record of the development of naval ordnance from wooden gun carriages and iron cannon to the most modern automatic weapons and guided missiles. It is also the story of the civilian employees of the Yard and Gun Factory who have rendered one hundred and fifty years of unbroken

service to the people of the United States and their Navy."[2]

2. Factory Location

The factory is located in Washington within the boundaries of the District of Columbia. The buildings are located in an area of 125 acres along the Anacostia River.

3. The Market

The national market is represented by the United States Armed Forces. As an example of the international market we can give Brasil, which bought fire control equipment during the last World War.

4. Labor

At Navy Department Headquarters there is a Department Civilian Personnel Director who has the responsibility of developing and recommending to the Office of Industrial Relations policies and precedures. The OIR is concerned with the Navy's entire civilian personnel. 38.5% of the Navy's manpower is comprised of civilians.

For graded or classified jobs, each position is evaluated and its proper grade and salary level determined. For unclassified jobs, the wages are set in accordance with prevailing local rates in the Washington, D.C. area as required by governing legislation.

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[2] Taylor Peck, "Round Shot to Rockets", U.S. Naval Institute, Annapolis, 1949.

The workers in the factory are divided in two groups, classified and unclassified.

- 4-1 - Unclassified:
    - 4-11 - Unskilled laborers.
    - 4-12 - Laborers and helpers.
    - 4-13 - Journeymen.
    - 4-14 - Supervisors.
- 4-2 - Classified:
    - These include all employees whose positions are classified into grades and services and whose salaries are set by the classification Act of 1949.

The workers have a probational period.

In the case of 4-11, 4-12, 4-13, the employee is hired for a specific job such as machinist, painter, etc... He is not expected to work outside of his trade.

In the case of 4-14, the employee is hired to fill a job for which a detailed job description has been written. The salary is determined on the basis of this job description.

A 40-hour week is established by law for both classified and unclassified personnel. Normally the work week comprises 5 days of 8 hours each. In excess of 40 hours per week, the employees are entitled to overtime.

As government employees, they are denied the right to strike.

There are two types of retirement, retirement for age, or length of service and disability retirement.

There is an "Efficiency Rating System" for the classified and for the unclassified group. For the unclassified group the system adopted is called "Shop Efficiency Rating System". There are regulations governing the use of these systems, but they operate on the same basic principles. Both require an employee's supervisor at stated intervals to evaluate his performance by specified factors, to reduce this evaluation to writing, to have this rating reviewed, and to allow him to discuss it if he wishes. Both provide appeal procedures.

It is the responsibility of the factory to furnish necessary training to allow the employee to maintain and improve his skills. The Navy's "Employee Development Program" includes several types of training.

In the factory there are the so-called "white collar" group consisting of clerical, professional, technical, accounting, administrative and other similar types of "office" positions, and the so-called "blue collar" group, consisting of labor, helper, mechanical, supervisory or "shop" positions.

The classification and pay of the white collar group is covered by the classification Act of 1949.

The"blue collar" positions involving groups 4-11, 4-12, 4-13, 4-14, have wages rates based upon wage data for comparable jobs in the labor market area.

I - DETERMINATION OF THE ORGANIZATION OF THE INDUSTRIAL ENTERPRISE

a)

Structure of the Organization; Organization Charts.

Reference: Chart No. 4.

The United States Naval Gun Factory is under control of the Bureau of Ordnance, Navy Department.

Following the chart No. 4 (structural), we can see that its affairs are administered by the Superintendent, a naval officer of flag rank, through the heads of the following departments:

1) Management Planning and Review.
2) Industrial Relations.
3) Fiscal.
4) Administrative.
5) Medical.
6) Planning.
7) Engineering.
8) Supply.
9) Production.
10) Inspection.
11) Public Works.

To understand the complexity of this organization we must remember that the factory must be ready to meet ever-widening demands in the fields of metal fabrication, machining, and optical, electrical and electronic development in connection

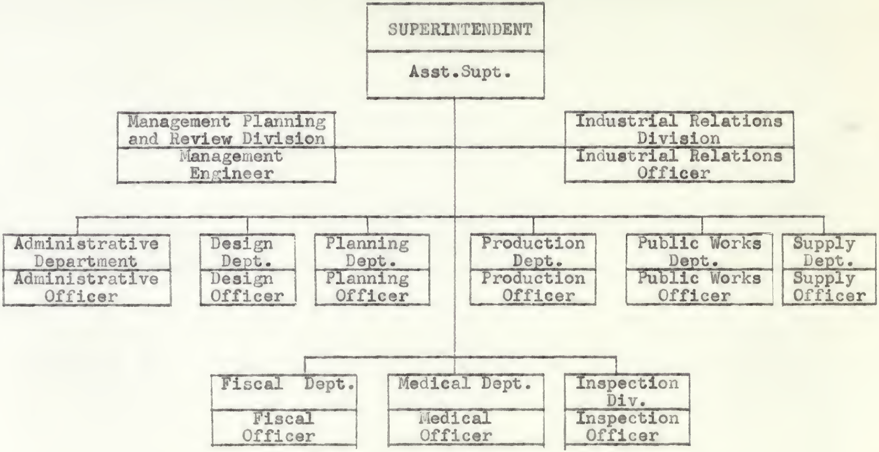

SUPERINTENDENT
Asst.Supt.
Management Planning and Review Division
Management Engineer
Industrial Relations Division
Industrial Relations Officer
Administrative Department
Administrative Officer
Design Dept.
Design Officer
Planning Dept.
Planning Officer
Production Dept.
Production Officer
Public Works Dept.
Public Works Officer
Supply Dept.
Supply Officer
Fiscal Dept.
Fiscal Officer
Medical Dept.
Medical Officer
Inspection Div.
Inspection Officer

CHART NO. 4 - STRUCTURAL ORGANIZATION CHART.

with ordnance for the air, surface, and sub-surface units of the fleet.

To study the structural and functional organization, we must first consider the mission of the Gun Factory. This mission is to design, develop, manufacture, assemble, inspect and test ordnance equipment. This includes guns and mounts of all calibers and types, aviation ordnance, torpedo tubes, rocket launchers, projectiles, fire control equipment, optical equipment, cartridge cases, spare parts, tools and accessories, and other ordnance materials as directed by the Bureau of Ordnance.

The Gun Factory also:

1) Serves as a source of prototypes of new weapons.
2) Overhauls, maintains, and stores ordnance material.
3) Operates the Naval Ordnance Gage Laboratory and administers the Final Acceptance Gage Program.
4) Provides technical consultation service, with relation to ordnance material, to other naval activities and to private industry.
5) Maintains and operates laboratory facilities for the examination, development, testing and standardization of materials and techniques for ordnance purposes.
6) Prepares and maintains manufacturing records, drawings, and reproduction data, and makes them readily available to other prospective manufacturers.

Chart No. 4, here reproduced, shows the general structure of the oldest and most important manufacturing plant under the Bureau of Ordnance, which has been, and which continues to be, the primary source of supply of the guns of the Navy.

b)

LINE OF AUTHORITY, DEGREES OF RESPONSIBILITY AND CORRESPONDING DUTIES IN THE ORGANIZATION

The Bureau of Ordnance of the Navy Department controls the factory.

The highest administrator is the Superintendent, a naval officer with the rank of Admiral.

Department heads are naval officers qualified by training and experience in their respective fields.

Civilian supervisory personnel are carefully selected from capable, highly trained employees in the numerous trades and crafts at the Gun Factory. Many of them are specialists nationally recognized for their outstanding ability.

c)

POSITION OF PRODUCTION PLANNING IN THE ORGANIZATION

Reference: Charts Nos. 5, 6 and 7.

The present factory is a series of shops doing a multitude of tasks, with all the work coordinated into a general master plan of design and production.

The departments of the Gun Factory are inseparable pieces in the coordination of the machinery of the plant, however, this report is primarily concerned with the production department.

The production department is comprised of 21 shops which manufacture various elements of ordnance. Its acti-

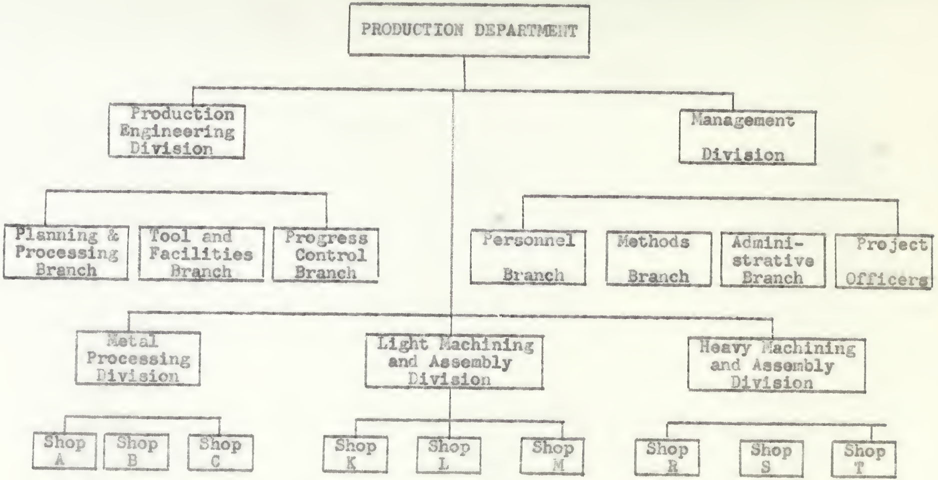

PRODUCTION DEPARTMENT
Production Engineering Division
Management Division
Planning & Processing Branch
Tool and Facilities Branch
Progress Control Branch
Personnel Branch
Methods Branch
Administrative Branch
Project Officers
Metal Processing Division
Light Machining and Assembly Division
Heavy Machining and Assembly Division
Shop A
Shop B
Shop C
Shop K
Shop L
Shop M
Shop R
Shop S
Shop T

CHART NO. 5 - PRODUCTION DEPARTMENT - STRUCTURAL ORGANIZATION.

vities have been divided into five divisions:

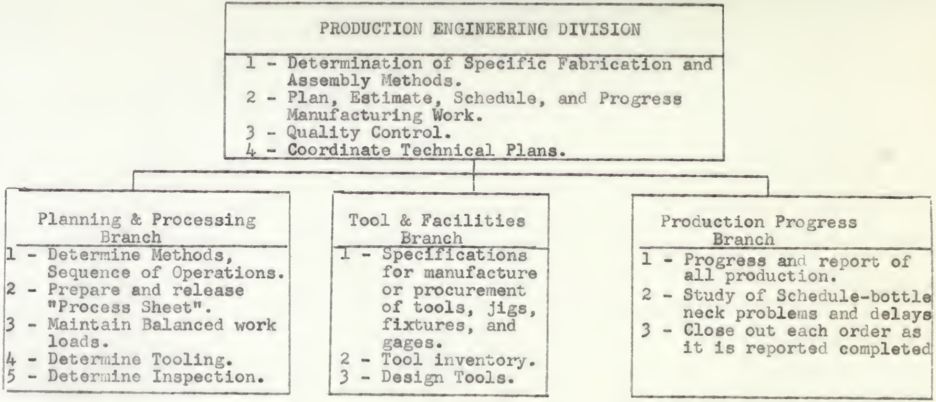
1 - Production Engineering Division.
2 - Management Division.
3 - Metal Processing Division.
4 - Light Machining and Assembly Division.
5 - Heavy Machining and Assembly Division.

To find the position of production planning in the organization, we must first take the production engineering division of the production department and study the functions of this division. One of these functions is, "The determination of specific fabrication and assembly methods, and related equipment."

If we now take Chart No. 6 of the Production Engineering Division of the Production Department, we can locate the so-called "Production Planning Function" in the branch called "Planning and Processing".

The functions of the "Planning and Processing Branch" are to:

1 - Determine methods, operations, and sequence of operations.
    1-1 - Prepare and release "Process Sheet."
2 - Improve methods or tooling in critical segments of the programs.
3 - Estimate of cost.
4 - Determine machine loading and man-hours of work required.
5 - Maintain balanced work loads in the production shops.



PRODUCTION ENGINEERING DIVISION

1 - Determination of Specific Fabrication and Assembly Methods.
2 - Plan, Estimate, Schedule, and Progress Manufacturing Work.
3 - Quality Control.
4 - Coordinate Technical Plans.

Planning & Processing Branch

1 - Determine Methods, Sequence of Operations.
2 - Prepare and release "Process Sheet".
3 - Maintain Balanced work loads.
4 - Determine Tooling.
5 - Determine Inspection.

Tool & Facilities Branch

1 - Specifications for manufacture or procurement of tools, jigs, fixtures, and gages.
2 - Tool inventory.
3 - Design Tools.

Production Progress Branch

1 - Progress and report of all production.
2 - Study of Schedule-bottleneck problems and delays
3 - Close out each order as it is reported completed

CHART NO. 6 - PRODUCTION ENGINEERING DIVISION.

The head of the "Planning and Processing Branch" decides what has to be done and where, when and how it is to be done.

In order to determine what has to be done to make the product, and to list all the necessary work, it is necessary to make an analysis of the operations. This means the required manufacturing operations are listed as well as the sequence in which they must be performed. The "Process Sheet", used for this listing corresponds to the "Standard Process Sheet", used in GE 183.

The comparison of this sheet, with the "Standard Process Sheet" studied in GE 183, will be done in the second part of the procedure.

d)

COMMUNICATIONS BETWEEN PRODUCTION PLANNING AND OTHER BRANCHES OF THE ORGANIZATION

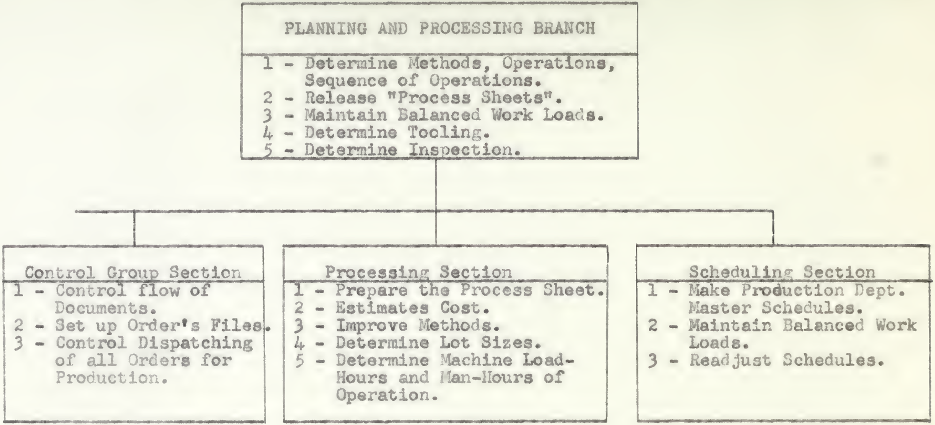
Reference: Charts Nos. 4, 5, 6 and 7.

The engineering department prepares the "Project Prospectus", which includes information concerned with the schedule, blueprints, stock materials, commercial materials, tools, and spare parts; and sends them to the production department.

The master copy of the "Project Prospectus" is filed in the engineering department.

The "Work Authorization Form" is written in the planning department and is sent to the production department.

These basic data are sent from the office of the production department to the planning and processing branch via the



PLANNING AND PROCESSING BRANCH

1 - Determine Methods, Operations, Sequence of Operations.
2 - Release "Process Sheets".
3 - Maintain Balanced Work Loads.
4 - Determine Tooling.
5 - Determine Inspection.

Control Group Section

1 - Control flow of Documents.
2 - Set up Order's Files.
3 - Control Dispatching of all Orders for Production.

Processing Section

1 - Prepare the Process Sheet.
2 - Estimates Cost.
3 - Improve Methods.
4 - Determine Lot Sizes.
5 - Determine Machine Load-Hours and Man-Hours of Operation.

Scheduling Section

1 - Make Production Dept. Master Schedules.
2 - Maintain Balanced Work Loads.
3 - Readjust Schedules.

CHART NO. 7 - PLANNING AND PROCESSING BRANCH.

production engineering division.

In the planning and processing branch, the "Work Authorization Form" is sent to the "Control Section" and basic data required is taken for the preparation of the "Process Sheet".

The Project Prospectus sheet No. 2 (Master Schedule) is sent to the Scheduling Section for purposes of schedule estimates, and to maintain a balanced work-load in each shop. The other sheets of the Project Prospectus are sent to the Processing Section, for tool requirements, gages, and for planning the detail fabrication of the products, determining and recording methods and sequence of operations.

The Process Sheet, when completed, is sent from the Production Engineering Division to the office of the Production Department, and then distributed to one of the Metal Processing, Light Machining and Assembly or Heavy Machining and Assembly divisions, where the product will be manufactured.

The blueprint and the operator's instruction chart accompany the Process Sheet.

II - DETERMINATION OF THE OPERATION OF THE U.S. NAVAL GUN FACTORY

a)

Manufacturing of the Product

The manufacturing process consists of three distinct parts:

1 - Manufacture of the ingot.
2 - Manufacture of the gun barrel forging.
3 - Manufacture of the gun barrel.

Manufacturing of the ingot

The Naval Gun Factory makes its own steel. The Foundry is housed in four buildings: Steel Foundry, Brass Foundry, Brass Casting Cleaning Shop, and Smelting Plant. The largest of these is the Steel Foundry, which is housed in a building 600 feet long by 132 feet wide.

The melting department of the steel foundry consists of:

a) One 7-R Heroult Top Charge Electric Melting Furnace.
b) One 25-R Heroult Top Charge Electric Steel Melting Furnace.

These furnaces are limited by the amount of electric power which can be produced by the Naval Gun Factory to a maximum production of 100 tons of steel every 24 hours, when operating on a three shift basis.

The chemical composition of the steel required to make the 5"/38 gun barrel, with minor variations in the percentages

of the components, is the same as is used in the National Forge & Ordnance Co.

What was said about the process of manufacturing of the ingot in reference to the National Forge & Ordnance Company can also be applied to the Naval Gun Factory.

The dimensions of the ingot are as follows:

Maximum length	11' 1.5"
Length of the octagonal part	8'
Maximum diameter (octagon)	30"
Minimum diameter (octagon)	22"
Length of the cylindrical part	33"
Diameter of the cylindrical part	18.96"

The wood model of the ingot is manufactured by skilled pattern makers in the pattern shop. As the quantity of the ingots is large enough to require the use of a metal pattern, the wood model is reproduced in metal. In this shop more than 300,000 patterns of parts manufactured during the past twenty years are stored. The ingots are cast in metal molds of the most modern type, with adequate hot tops.

Manufacture of the gun barrel forging.

Forging, or the shaping of metal heated to a plastic state to the desired contour and dimension, requires powerful machinery.

The major unit in the Forge Shop is a 2,000 ton steam-hydraulic forging press, with the necessary auxiliary equipment, i.e., a 30 ton overhead traveling crane and a battery of oil-fired heating furnaces with pneumatic door lifts. At

this machine the majority of guns required by the Navy in the two world wars were produced.

From the foundry the ingot is taken to the forge, where it is brought to the forging temperature of 2,100° F.

The ingot is balanced by means of a porter bar and taken by an overhead crane to the hydraulic forging press. There the ingot is forged by repeated workings, the pressure being applied gradually for about three seconds, with one second intervals between pressure applications. The forging operation is discontinued when the ingot has cooled to about 1550° F.

The entire body of the ingot must be charged in the heating furnace and heated for forging, and the first forging operation covers the entire ingot.

The cooling of the forging is controlled in such a manner as to insure that the temperature throughout the metal is equalized at above 1200° F., and that the rate of cooling from this temperature of equalization to 600° F. is slow and uniform.

The gun barrel forgings are required to be uniform in quality and free from pipes, cracks, flakes, hard spots, and from all other defects that may affect their strength.

Manufacture of the gun barrel.

The gun shop is housed in a building with a floor area of 139,000 square feet, or slightly more than three acres. It is a versatile shop. It permits the accomplishment of a considerable number of projects at one time. Its work program is not confined to large guns, but has included the fol-

lowing types of ordnance:

1) 3"/70 prototype
2) 5"/38
3) 5"/70 prototype
4) Rocket launchers
5) Catapults
6) 3" 50 modifications
7) 5"/3" .75 squeeze bore gun

For the large guns, a very intricate method of assembling several forgings by expanding and shrinking is used.

For the 5"/38 gun the process is in general the same as was outlined when the National Forge & Ordnance Co. was studied. The forgings are rough bored and rough turned before heat-treatment.

At the Naval Gun Factory, the fifth operation, layout to drill end for heat-treat; and the sixth operation, drill 4¼" hole, are not made. Instead, a collar is left on the muzzle end of the forging to support the forging during heat treatment. This collar does not cover any part of the finished forging, and is used so the crane can hold the gun barrel in a vertical position for heating and quenching.

No forgings are quenched except after sufficient rough machining to remove all forging scale and other surface defects. The methods and arrangements are such that a current of the quenching fluid flows freely through the bore.

According to the specifications no forging shall be quenched more than five times, but the number of drawing

operations made after any quenching operation if not limited.

Straightening after heat treating, when necessary, is carried out at a temperature not lower than 800° F. and not higher than 150° F. below last heat treatment temperature. Straightening is defined as the removal of a bow or arc in the forging not exceeding .004" per inch of forging length over which the bow or arc extends.

The physical laboratory uses transverse and longitudinal specimens cut from the ends to determine whether the alloy meets the necessary physical requirements, which are:

	Transverse Specimen	Longitudinal Specimen
Tensile strength (lb.per sq.in.)	90,000 minimum	90,000 minimum
Yield strength (lb.per sq.in.)	65,000 minimum	65,000 minimum
Elongation (in 2 in.,per cent)	18 minimum	21 minimum
Reduction of area (per cent)	30 minimum	40 minimum

The disks from which physical test specimens are to be taken are used for metallographic examination. Disks and specimens are polished and ground whenever macro and micro-etching must be done. The specimens must not show porosity, non-metallic inclusions, segregations, cracks or flakes.

The fracture of any tension must not show any stratification, lamination, or earthy or woody appearance.

The term "runout", used in many operations during the process, means the total displacement registered by an indicator at any transverse section of an end-centered forging during one complete revolution. Forgings having a runout not

exceeding 150 percent of the value specified on the drawings are considered acceptable.

The equipment used for radial expansion consists of two electrically driven pumps, of the three cylinder type, with a capacity of 1½ gallons per minute at a pressure of 5,000 lb. per sq. in.

The intensifier is double acting and has pistons of the ratio of 26.5 to 1.

The maximum permissible runout of the outside diameters before radial expansion is .025". The bore of the forging is starguaged for each inch of its length, before the operation.

If a section of the forging fails to withstand the prescribed expansion pressure, the physical properties of the forging at the weak section can usually be improved by cold working followed by the proper low heat and aging. The procedure consists of giving the prescribed low heat temperature treatment, aging for 10 days, and then setting up for re-expansion of the deficient stage.

The pack bits used for gun boring are manufactured in the carpenter shop, which is one of the few plants in the country producing these items. The wood used is maple which is dried to the desired moisture content.

To inspect the gun bore surface the Naval Gun Factory makes a local bore photograph at a magnification of 12x with a N.G.F. designed and manufactured boroscope. Local photographs of bore conditions are made at various stages of manufacture.

The Bureau of Ordnance established the Gage Division at the Naval Gun Factory, for the purpose of assuring rapid and accurate inspection. The Gage Division of the Planning Department supplies gages to all inspectors. They use an electrical bore gage to obtain internal diameter readings in the gun barrel. This very modern device for inspection permits rapid, accurate, and continuous readings of gun bore dimensions and presently is very useful in inspection and gun erosion tests. The laboratory of the division calibrates and examines individual gages to determine their conformity to specifications and their suitability as final acceptance inspection gages.

In conformance with the international temperature standard for calibration of gages the laboratory is maintained at 68° F. ± 1° F., and to minimize corrosion the humidity is limited to 40% ± 5%.

The basic measuring elements of the laboratory, the gage blocks, are continually checked, and their measurements are known to one-millionth of an inch.

A very important point to be considered in the operation of the Naval Gun Factory is the high efficiency of the Laboratory Division in all phases of manufacturing. The laboratory facilities include a chemical laboratory, mechanical testing laboratory, melting laboratory, welding laboratory, heat treatment laboratory, stress analysis laboratory, metallography laboratory, and such non-destructive testing equipment as a 1,000,000 volt X-ray machine, magnaflux machines and

reflectoscopes.

These services by making specialized tests and analysis of material, provide all facilities needed for controlling the quality of the Naval Gun Factory products.

As a summary of the manufacture of the gun barrel in the Naval Gun Factory, we can say:

After forging -

a) Forgings are rough turned between centers.
b) Forgings are rough bored to 4".150.
c) Forgings are rough turned on outside diameters to:
    a) 13.65"
    b) 12.75"
    c) 11.00"
    d) 9.25"
d) Forgings are heat-treated.

Before Radial Expansion -

1) Second rough bore is done, using a packed bit, to a diameter of 4.50".
2) Third rough bore is done, using a packed bit, to a diameter of 4.65".
3) Using the last bore as center, the forging is set on centers and rough turned to within .003" of the outside diameters:
    a) 13.15"
    b) 12.25"
    c) 10.50"
    d) 8.75"

Radial Expansion.

1) The barrel is set up in the radial expansion equipment.
2) Expanding operations are then performed using pressure from 79210 p.s.i. for stage one, to the final pressure for stage four equal to 45,200 p.s.i.

After Radial Expansion.

1) Re-expand the forging if necessary.
2) Inspect.
3) Finish bore.
4) Hone.
5) Finish turn.
6) Rifle.
7) Bore out chamber.
8) Grind chamber.
9) Cut threads.
10) Interrupt threads.
11) Machine extractor slots.
12) Cut key way.
13) Chrome plate.
14) Polishing.

The last operation is performed in "Polishing and Plating", a separated activity which was started at the Naval Gun Factory in 1898. In 1908 electroplating tanks for nickel, copper and silver were installed. The modern electroplating plant, with particular emphasis on chromium plating the bores of major caliber gun barrels, was installed in 1928.

The first gun barrel was chromium plated in 1928 and from tests it was considered of sufficient value to justify the continuation of chromium plate gun barrels.

b)

PLANT EQUIPMENT

It seems clear that there is no job within the limitations of its space that the Gun Factory cannot perform. The equipment which was geared primarily to the manufacture of armament, can be converted to the production of material other than weapons of war.

The present factory is a series of shops, doing a multitude of tasks, yet with all the work coordinated into a general master plan of design and production.

A summary showing, for each shop of the Naval Gun Factory, the machines required to manufacture the gun barrel, will be given. This method of attack will be different from the method used for the similar study made at the National Forge & Ordnance, due to the different functions of these two enterprises.

Metal Processing Division.

1 - Foundry.

1) 7-R Heroult Top Charge Electric Steel Melting Furnace.
2) 25-R Heroult Top Charge Electric Steel Melting Furnace.
3) Hydraulic Ingot Stripper.

4) Heating Soaking Pitt.

2 - Pattern and Joiner Shop.

1) Lathes - wood turning, 36" diameter.
2) Swing saws - capacity 6" thick to 23" wide.
3) Band saws - 30" to 42" capacity in width.
4) Circular saws.
5) Milling machines.
6) Sanding machines.
7) Mortise and Tenon machines.
8) Routers.
9) Moulding machines - 4" thick, 8 to 12" wide, self-feeding.

3 - Forge Shop.

1) 2,000 ton steam hydraulic forging press.
2) 30 ton ground controlled overhead traveling crane.
3) Battery of oil fired heating furnace with pneumatic door lifts.
4) Porter bar.
5) Saws.
6) Vertical furnaces for heat treatment, 6' dia. x 60' deep.
7) Quenching tanks for oil and water, 6' dia. x 60' deep.

Heavy Machining and Assembly Division.

1 - Gun Shop.

1) 11 Engine lathes, capacity 30" dia., 30' long.
2) 3 Engine lathes, capacity 82" dia., 80' long.
3) 4 Engine lathes, capacity 96" dia., 88' long.
4) 2 Engine lathes, capacity 20" dia., 6' long.
5) 2 Engine lathes, capacity 10" dia., 30" long.
6) 2 Engine lathe, capacity 22" dia., 16 ft.long.
7) 1 Engine lathe, capacity 16" dia., 16 ft.long.
8) 1 Boring machines - 16-3/4 x 28' 6".
9) 3 Boring machines - 82" dia., 78' long.
10) 8 Boring machines - 96" dia., 90' long.
11) 6 Boring machines - 26" dia., 25' long.
12) 3 Boring machines - 13" dia. x 22' long.
13) 1 Boring machine - 30" dia. x 90' long.
14) 4 Boring machines(le Blond)-Maximum speed 240 r.p.m.
15) 3 Radial drill presses - 5'.
16) 2 Rifling machines, capacity 3" to 8" guns.
17) 2 Rifling machines, capacity 8" to 18" guns.
18) 1 Broach machine for rifling.
19) 2 Honing machines, capacity 3" to 8" guns.
20) 2 Honing machines, capacity - greater than 8" guns.
21) 2 Universal cylindrical grinders - capacity from .50" to 30". Dia., 10' long.
22) 1 Cylindrical grinder, capacity .50" to 30" Dia., 10 ft. long.

23) 3 Cutter grinders.
24) 1 Lipping grinder for bits.
25) 1 Surface grinder, 10" dia. x 60' length.
26) 2 Chamber grinder.
27) 1 Vertical Milling Machine, 18"x 16"x 4'.
28) 2 Thread Mill.
29) 1 Planer, 15' wide, 25' stroke.
30) 1 Planer, 3' wide, 6' stroke.
31) 3 Shapers - 32" stroke.
32) 3 Lapping machines.

c)

LAYOUT OF THE PLANT

The size of the industrial organization is an important consideration in the making of the layout. The factory has 188 buildings that sprawl over 125 acres along the Anacostia River.

The factory set-up is so diversified that it is very difficult, considering the limitations of this thesis, to insure the necessary precision in making a drawing of the layout involving all phases of the manufacture of a gun barrel.

The 21 shops which are engaged in the manufacture of various elements of ordnance are grouped into three major categories:

a) Metal Processing.
b) Light Machining and Assembly.
c) Heavy Machining and Assembly.

In each category we will give the names of the shops which are involved in the manufactur of the gun barrel.

Metal Processing Division.

1 - Foundry - castings in steel.

2 - Pattern and Joiner shop - Pattern for casting and manufacturing of pack bit tools for boring.

3 - Plating and Polishing - polishing and chromium plating.

4 - Forge - Heavy, medium, and light forgings. Heat treatment.

Light Machining and Assembly Division.

1 - Tool shop - Manufacture of tools, jigs and fixtures.

Heavy Machining and Assembly Division.

1 - Gun Shop - Manufacture and repair of guns of the following types of ordnance:

1) 3"/70 prototype.
2) 5"/70 prototype.
3) 5"/38
4) 5"/54
5) 3"/50
6) 3"/50 - platforms
7) Details of rocket launcher.
8) Catapults.
9) 3"/50 - modifications.
10) 3"/50 - squeeze bore gun.

The machines in these shops are in general grouped according to the type of operation they perform. We can say that, in

general, the Naval Gun Factory uses the "layout by process". This means that all engine lathes are installed in one section, boring machines in another, etc...

Where a variety of products are produced at irregular intervals, this method is preferred. It has the advantage of maximum flexibility as far as machine usage and capacity are concerned.

III - DETERMINATION OF THE PAPER WORK INVOLVED IN PRODUCTION PLANNING IN THE U.S. NAVAL GUN FACTORY

a)

Standard Process Sheet.

Reference: Figure No. 6.

In this factory the "Standard Process Sheet" is known by the code: PRNC-972a (Rev. 10-48).

The Standard Process Sheet, called just "Process Sheet" in this organization, is prepared in the Processing Section of the Planning and Processing Branch, which is part of the Production Engineering Division of the Production Planning Department.

1 - Definition.

A Process Sheet is a listing of the work required to modify a product.

2 - Purposes.

The purposes for which a Process Sheet may be used are:

1) To specify all production operations in their proper sequence, following a predetermined processing method.
2) To ascertain materials, tools and gages necessary.
3) To establish man-hour allowances for manufacturing operations and set-up time.
4) To assign work to shops and to functional groups within the shops.

PRODUCTION JOB ORDER (PROCESS SHEET)
Prnc-NGF-972a(Rev.10-48 Sheet______ of______

Serial Sheet Dated No.	Supersedes Sheet Dtd.	Prepared by	Checked by	Examined by	Approved(For P1-20) (Date)

Shop No.	Oper. No.	TOOLS & GAGES		Mach. Group No.	Oper.Desc.	Code	S.D.C.	MACH.LOAD HRS.			Total Labor/ Hrs.(Allow 10% f/Cont'g	Estimated Cost
		S.A.No.	Name					Setup Total	Oper. /100	Total		

Material Identification & Quantity	Schedule Compl.	Date	Starting Date	Completion Date	Board No.
	Stock Mat.				
	S-A Dwgs.		Quantity	Mfg.lot size	Line No.
	S-A Tools				
Station Appropri-ation Account OCL OCM	Patterns		For Assembly Dwg.No.		Dwg.Rev. (Pieces)
	Forg.Dies				

Allot/Proj. No.	Job Order No.	Dwg.& Piece No.	Drawing and piece name (Abbreviate)

FIGURE NO. 6

5) To determine the estimated cost.

3 - Responsibilities.

The Process Sheet is under the jurisdiction of the head of the production department who exercises line direction over the entire manufacturing process. He makes a general review of the processing and tooling planned by the head of the Processing Section of the Production Engineering Division. The supervisor of the shop reviews the processing and tooling from a craft point of view, to plan its accomplishment within the shop, to note any discrepancies which may have been overlooked and call them to the attention of the authority immediately above him, or to propose alternative methods better suited to the shop consitions.

4 - Standard Operation Procedure.

1) The Production Department receives the "Work Authorization" form (code:PRNC-NGF-1303) from the Planning Department, and the "Project Prospectus" from the Engineering Department, and makes the process sheet.

2) The process sheet is organized by the "Heavy Machining and Assembly team" of the Processing Section, in the case of the gun barrel. Everything concerning tool facilities is done in the Tool and Facilities branch of the Production Engineering Division of the Production Department.

3) After a general review and criticism of the processing and tooling planned by the Production Engineering Division, the Production Manager, head of the Production Department, sends the process sheet to the supervisor of the Heavy Machining and Assembly Division. This supervisor is in charge of three shops, one of which is:

a) Shop R (Manufactures, assembles, inspects, overhauls, repairs, reconditions, and preserves heavy ordnance mechanisms and component parts, such as gun barrels.)

The Supervisor of the Heavy Machining and Assembly Division, together with the foreman of "Shop R", reviews the processing and tooling specified by the Production Engineering Division, in order to evaluate its soundness from a craft standpoint.

5 - Drawing of the form.

1) Head -

a) Title: Production Job Order (Process Sheet)
b) Code: PRNC-NGF-(Rev. 10.48)
c) Sheet _____ of_______
d) Serial number.
e) Sheet dated
f) Supersedes sheet____
g) Prepared by
h) Checked by
i) Examined by
j) Approved (date)

2) Body -

a) Shop number.

The Routing Section in accordance with the "work-station load chart" furnishes this element to section 2 of the "Project Prospectus".

b) Operation number.

The numbers in this column indicate the sequence of operations.

c) Tools and gages.

The purpose of these last two columns is to provide the number and the name of the special tools and the special gages required for each operation.

The standard tools and gages will be referred to as "standard" in these columns. To fill these columns the "tool and gage team" furnishes a complete list of the tools available.

Special tools and gages not available cannot be ordered until the detailed drawings of the parts to which they apply have been made by the Engineering Department.

d) Machine group number.

After grouping the work units into operations and arranging the operations in the proper sequence, we now determine the group of machines within a department of a particular machine shop needed to perform the work.

In the case of the gun barrel the machine shop will be the "Shop R", of the Heavy Machining and Assembly Division,

which is one of five divisions of the Production Department.

e) Operation Description.

States the operations necessary to manufacture the article or part in the sequence established by the column "operation number". The work units are listed within each operation in the order required in the process.

f) Code of the operation.

g) Schedule Date.

To provide tentative information (at the earliest possible date) which may be used as a general guide in the planning of work to be performed by the Naval Gun Factory, the "Project Prospectus" has in its second section the "Master Schedule".

This section is a Giant Chart type of master schedule. The first sheet will be the overall assembly schedule. For each assembled unit there will be a master schedule sheet. Thus, we can have for each operation a tentative schedule date, based on the master schedule sheet of the gun barrel. The scheduling section of the Planning and Process Branch maintains a balanced work-load in the shop to meet master schedule needs.

h) Machine load hours.

In considering the quantity of work assigned to the machine at each operation the form expresses it as the total number of hours of work in setting up the machine and in operating it. The machine load for a specific order can then be ascertained by multiplying the unit time allowance by the which is one of five divisions of the Production Department.

e) Operation Description.

States the operations necessary to manufacture the article or part in the sequence established by the column "operation number". The work units are listed within each operation in the order required in the process.

f) Code of the operation.

g) Schedule Date.

To provide tentative information (at the earliest possible date) which may be used as a general guide in the planning of work to be performed by the Naval Gun Factory, the "Project Prospectus" has in its second section the "Master Schedule".

This section is a Gantt Chart type of master schedule. The first sheet will be the overall assembly schedule. For each assembled unit there will be a master schedule sheet. Thus, we can have for each operation a tentative schedule date, based on the master schedule sheet of the gun barrel. The scheduling section of the Planning and Process Branch maintains a balanced work-load in the shop to meet master schedule needs.

h) Machine Load Hours.

In considering the quantity of work assigned to the machine at each operation the term expresses it as the total number of hours of work in setting up the machine and in operating it. The machine load for a specific order can then be ascertained by multiplying the unit time allowance by the number of pieces in the lot on order.

i) Total labor/hrs.

The standard time is set operation by operation, to give the total labor hours for each operation. This total labor hours is divided into two elements, set-up and operation. These standard times in the manufacture of gun barrels are obtained from existing data based on many years of experience.

It is one of the functions of the "Processing Section" to make plans and estimates of machine loading and man-hours of work load.

j) Estimated Cost.

Based on previous data accumulated as a result of long experience in this kind of manufacturing the Processing Section knows the rate per hour required to perform each of the operations listed in the Process Sheet. The column "Estimated Cost" gives the price of each operation based on the total labor hours of operation and on the value of the rate/hour of each machine involved in the operation.

3) Bottom -

a) Material Identification and Quantity

The sections 4,5,6,7 and 8 of the Project Prospectus will furnish:

4 - Stock materials.

5 - Commercial materials.

6 - Casting and Forgings

7 - Bars, Rods, Sheets, Plates, Shapes, Pipe, and Tubing.

8 - Miscellaneous materials.

b) Job Order number.

c) Drawing and piece number.

d) Schedule Date relative to: Stock materials, Drawings, Tools, Forging and Dies.

e) Starting date.

f) Completion date.

g) Quantity.

h) Manufacturing lot size.

i) For Assembly Drawing Number:

(1)-Drawing Revisions.

4) Back Sheet -

a) Summary of Schedule and Cost.

Code: 972b (Rev- 5-48)

This summary is divided in two parts:

1 - Material lot schedule.

2 - Manufacturing lot schedule.

Each one has the same number of columns which are the shop number or letter, the operation number, the number of pieces required by the schedule, and the number completed by the respective dates. These two last columns are filled in according to "lot number". There are other similar columns for other lots. This part of the sheet is prepared by the Scheduling Section of the Planning and Processing Branch.

b) Summary Cost Data by Shop (estimate)

It is an accepted practice when estimating the cost of products to divide the cost into three main divisions:

1 - Labor

2 - Material.
3 - Overhead.

In this part of the sheet, the supervisor of the shop estimates cost for work being considered. The sheet has the following columns:

1 - Shop number or letter.
2 - Man-hours
3 - Labor cost
4 - Material
5 - Overhead
6 - Total

c) Actual Operating Time.
Charged Man-hours.

This part is to be filled out by shop when each operation is completed. There are four columns:

1 - Set-up time.
2 - Operation.
3 - Time lost.
4 - Total.

As we said in the Standard Operation Procedure, the Process Sheet is made after the Production Department receives the "Work Authorization Form" from the Planning Department, and the "Project Prospectus" from the Engineering Department.

In this item we will summarize the functions of those forms from which the "Process Sheet" is originated.

1 - Production Work Authorization Form.

PRODUCTION WORK AUTHORIZATION Job Order Series Number
PRNC-NGF-1303

PREPARE TO MFR. THE FOLLOWING UNITS AS PER INSTRUCTIONS HEREIN

No.of Units Name of this Unit	FOR (Name of major task)

MARK PARTS LIST AS APPROPRIATE:
(M - Parts to be fabricated and machined)
(S - Parts to be drawn from finished store)
(S.F. - Parts to be taken from store and finished machined)
(S.S. - Standard stock parts) (P - Purchased)

Parts List	Proj.Prospectus	Schedule date of completion of these units

Additional information necessary to plan work.(This should contain data on materials, tools, drawings & parts to be furnished by the customer: Information on any special cost data required: Disposition information: Special tools, tests or production data known to be required: Etc.)

Man-Hrs.	Labor $	Material $	Indeterminate $	Total Estimate $

Station	Appropriation	Account	OCL	OCM	Funds Authorized by (date)

Allot./Proj.No.	Program Name(Abbreviation)	Planner(Date)

FIGURE NO. 7

Reference: Figure No. 7

Code: PRNC-NGF-1303

Purposes:

1) To clarify the responsibility for control of industrial work.
2) Provide a basis for controlling funds allocated to each order.
3) Authorization to commence production of a specified part piece.
4) To form a starting point for the control mechanism for one specified part piece. Issued by Planning Department under jurisdiction of the Product Department:
    a) Remain within the limitations of funds prescribed by the Planning Department in the "Work Authorization".
    b) Estimate and allocate funds in the detail required for production purposes and for reporting to the Planning Department any adjustments in requirements for funds.

2 - Project Prospectus Form.

Purposes:

1) To provide tentative information which may be used as a general guide in the initial planning of work to be performed.
2) To provide advance information for the use of the Supply Department in making a material

forecast.

3) To provide, after the authorization from the Planning Department, information to the Supply Department for procuring the material required.

4) To keep all activities informed as early as possible about everything concerning material for a project.

5) To provide the Production Department with the basic information to proceed with plans for manufacturing.

6) To provide a historical record of important elements of each project so handled.

Issued by Engineering Department under jurisdiction of Product Department.

a) Uses the information found in the Master Schedule (Sheet number 2) in the planning of Process Sheet.

b) Uses the material information found in sheets Nos. 4,5,6,7,8 and 10 in the planning of Process Sheet.

c) Uses the tool and gage information found on sheet No. 9 in the planning of the Process Sheet.

b)

Process Chart - Product Analysis.

Reference:Figure No. 8

Definition and symbols are the same as encountered in "Principles and PracticeMotion and Time Study", by H.E. Mundel.

This chart is issued by the Methods Branch of the Management Division, of the Production Department.

This branch has the following functions:

1) Investigate latest improvements in manufacturing processes.
2) Develop new methods and processes.
3) Maintain liaison with the design personnel for the development of new or improved manufacturing processes.
4) Make studies to determine the most efficient machines and tools for specific manufacturing purposes.
5) Initiate action for the standardization of the equipment.
6) Conduct methods research tests and experiments to further improvements.

c)

Operator Instruction Sheet.

This sheet is widely used in the Naval Gun Factory. Details of each particular operation and the sequence of steps to be followed are written, as well as the drawing or sketch concerned with the operation including all necessary dimensions and tolerances.

of Chart PROCESS CHART - PRODUCT ANALYSIS
Method ORIGINAL
eration MANUFACTURE OF COMPLETED PART
GUN BARREL (NGF MOD. 1)
t name GUN BARREL (NGF MOD. 1)
rator–
Machine No.
Operation No.
Part No. 101
Chart by DEL CASTILLO
Date charted MAY-3-1951

SYMBOL	EXPLANATION
○	CENTER -ROUGH TURN TO .003" OF FINAL DIA.
∘	TO BENCH
◇	INDICATE AND MARK RUNOUT
∘	TO RADIAL EXPANSION
○	RADIAL EXPANSION
∘	TO INSPECTION
◇	INSPECTION
∘	TO BORING MACHINE
○	FINISH BORE
∘	TO BENCH
◇	INDICATE AND MARK RUNOUT
∘	TO HONING
○	HONING
∘	TO ENGINE LATHE
○	FINISH TURN
∘	TO RIFLE
○	RIFLING
∘	TO ENGINE LATHE
○	BORE OUT CHAMBER
∘	TO GRIND
○	GRIND CHAMBER
∘	TO THREAD MILL
○	CUT THREADS
∘	TO PLANER
○	INTERRUPT THREADS-MACHINE EXTRATOR SLOTS AND

The form is divided into three parts:

Heading.

1. Part name.
2. Operation name.
3. Department name.
4. Machine Shop name.
5. Group of machines: number & name.
6. Quantity.
7. Order number.
8. Operation number.
9. Drawing by
10. Prepared by
11. Approved by
12. Date issued.

Body

1.- Sequence of operations.
2. Details of each operation.
3. How to perform each operation.
4. Tolerances for machining.
5. Tools to be used.
6. Feed.
7. Speed.

SECTION THREE

A COMPARISON BETWEEN THE U.S. NAVAL GUN FACTORY AND THE NATIONAL FORGE & ORDNANCE COMPANY

I - Comparison of the Organization of the Industrial Enterprises.

a) Structure of the Organization.

Reference: Charts Nos. 1,2,3,4,5,6,7 of the enterprises.

U.S.Naval Gun Factory	National Forge & Ordnance Co.
1) Under the control of Bureau of Ordnance, Navy Department.	1)Under the control of a board of directors, elected by the stockholders.
2) It is administered by the Superintendent, a naval officer of flag rank.	2) A president selected by the board of directors is placed in charge of the formation and supervision of the policies of the factory.
3) It has the following departments:	3) It has the following divisions that correspond to departments at the U.S.Naval Gun Factory.
a) Management Planning and Review.	a) Engineering.
b) Industrial Relations.	b) Financial.
c) Administrative.	c) Manufacturing.
d) Medical.	d) Testing Machines.

e) Planning.	e) Purchasing.
f) Engineering.	f) Sales
g) Supply.	
h) Production.	
i) Inspection.	
j) Fiscal.	
k) Public Works.	
4) Fields of interest:	4) Fields of interest:
Design, develop, manufacture, assemble, inspect and test:	Design, develop, manufacture, assemble and inspect:
a) Gun mounts of all calibers and types.	a) Gun mounts of certain calibers and types, under subsidization of the government.
b) Aviation ordnance.	b) Gun parts.
c) Torpedo tubes.	c) Crankshafts.
d) Rocket Launchers.	d) Eccentric Shafts.
e) Projectiles.	e) Piston rods.
f) Fire control equipment.	f) Shafts (all kinds)
g) Cartridge cases.	g) Turbines.
h) Spare parts for ordnance.	h) Valve forgings (special)
i) Accessories for ordnance.	i) Ingots (all kinds)
j) Tools for ordnance.	j) Billets.
k) Mine cases.	k) Machinery forgings.
l) Range finders and telescopes.	l) Railroad forgings.
m) Fuzes.	m) Rotor forgings.
n) Sights.	n) Smooth forgings.
o) Castings in steel, iron and non-ferrous metal.	o) Bars and boring bars.

U.S. Naval Gun Factory	National Forge & Ordmance Co.
p) Drop forgings.	p) Die blocks.
q) Other ordnance materials.	q) Rough and finished machined.

The first three items of the above comparison, show the great difference between one establishment controlled by the government and one private industrial organization.

The fourth item deals with the missions of the enterprises.

The U.S. Naval Gun Factory has a very complex structure ready to meet ever widening demands in the fields of metal fabrication, machining, and optical, electrical and electronic development.

The National Forge & Ordnance Co. has a simple structure where functions usually attributed to industrial relations and industrial engineering are placed in several other branches of the organization.

The fields of interest of the National Forge & Ordnance Co. are based on wide experience and extensive knowledge of how forgings should be made. They are not nearly as diversified as the NGF.

In the National Forge Co. the staff functions are centralized in the "front office," with a minimum of activities decentralized in the factory. This is a pattern of organization recommended for plants that have a single manufacturing division involving the manufacture of very closely related products.

The organization of the Naval Gun Factory is an example of one large industrial enterprise interested in many fields of production. The chart of the Production Department shows the complexity of this organization. The divisions of Production, Metal Processing, Light Machining and Assembly, and Heavy Machining and Assembly, each consist of three shops. These shops are organized also in accordance with a line-staff combination, with:

a) Administrative office.

b) Operations control section.

c) Production control unit.

d) Receiving and shipping unit.

e) Inspection Unit.

f) Manufacturing Section.

g) Assembly section.

h) Group of machines sections.

b)

LINE OF AUTHORITY, DEGREES OF RESPONSIBILITY, AND CORRESPONDING DUTIES IN THE ORGANIZATION

In both organizations there is delegation of authority which extends all the way through the factories from the superintendent or president to the supervisors, foremen and the workers at the bench.

Lines of communication work two ways: from the executive to the personnel, and conversely from the worker to those who are in authority over him. The structural aspect of the two organizations studied creates the framework. The personnel aspect of the organizations deals with the selection of individuals to fit into that design.

Finally, there is the control aspect of organization, which holds individuals to the performance of their assigned duties.

We will now make a comparison between the assigned duties of the main branches of the organizations in study.

U.S. Naval Gun Factory	National Forge & Ordnance Co.
1) Engineering Department	1) Engineering Department
a) Design, develop and modify designs of ordnance equipment.	a) Design, develop and modify designs of products manufactured by the company.
b) Engineering research on a large scale.	b) Engineering research on a very small scale.

c) Analysis, test, and evaluation work associated with ordnance development.	c) None.
d) Standards and specifications.	d) Standards and specifications.
e) Drawings and blueprints.	e) Drawings and blueprints.
f) Photographic service.	f) None
g) Publications.	g) Publications.
h) Quality control.	h) Quality control is a section of the Manufacturing Dept.
i) Ballistics and munitions.	i) Ballistics and munitions.
j) Analysis and computations.	j) Analysis and computation.
k) Production planning is a sub-division of the Production Dept.	k) Production planning. Analysis of operations. Standard process charts. Estimate Sheet. Improved Procedures. Time standards. Work simplification. Preparation of orders. Plant layout.
2) Production Department	2) Manufacturing Division
a) Metal Processing Division.	a) Melting Department.
a1) Produce ferrous and non-ferrous ingots and castings.	a1) Produce ferrous ingots and castings.
a2) Manufacture press forg-	a2) Forge shop, manufac-

ings and hammer forgings.	tures press forgings and hammer forgings.
a3) Heat-treatment operations.	a3) Heat-treatment shop does heat treatment operations.
a4) Flame-hardening.	a4) Flame-hardening shop does heat-treatment.
b) Light Machining and Assembly Division - Manufacture, assemble, inspect, test and repair.	b) None.
b1) Tools, gages, jigs, fixtures and dies.	b1) Cutting tools.
b2) Optional instruments.	b2) None.
b3) Assemble, test and calibrate electrical and electronic instruments.	b3) Repair and maintenance of electrical equipment.
b4) Light manufacturing and assemble.	b4) None.
c) Heavy Machining and Assembly Division.	c) Machine Department.
c1) Manufacture gun barrels.	c1) Manufacture gun barrels.
c2) Manufacture gun mounts.	c2) Manufacture gun mounts.
c3) Manufacture gun parts.	c3) Manufacture gun parts.
c4) Manufacture torpedo tubes.	c4) None.
c5) Manufacture rocket launchers.	c5) None.
c6) Perform heavy boring, turn-	c6) Perform heavy boring,

ing, milling, lapping, planing, drilling, rifling, honing, and grinding.	turning, milling, lapping, planing, drilling, rifling, honing, and grinding.
c7) Perform radial expansion.	c7) Perform radial expansion.
c8) Manufacture ordnance prototypes.	c8) None
c9) Assembly prototypes.	c9) None
c10) Perform pressure testing and operate controlled temperature rooms.	c10) None
d) Production Engineering Division.	d) None
d1) Planning and Processing branch.	d1) None
d11) Processing section; Production Planning	d11) Production Planning Dept. of the Engineering Div.
d2) Tool and facilities.	d2) Cutting tools section of Material Department.
d3) Process Control.	d3) Production Scheduling section of Material Control.
e) Management Division.	e) Personnel Department.
e1) Personnel branch.	e1) Personnel section.
e2) Methods branch.	e2) Production Planning division of Engineering Department.

e3) Administrative branch.	e3) None
e4) Project officers.	e4) None
e5) Security division of the Administrative Dept.	e5) Security section.
e6) Time keeping branch of Accounting division of the Fiscal Dept.	e6) Timekeeping section.
f) None	f) Material Control Dept.
f1) Supply Department	f1) Supply stores section.
f2) Inspection Department.	f2) Final inspection section.
f3) Shipping section of the Traffic branch of the Material division of the Supply Department.	f3) Shipping Section.
f4) Progress Control branch of the Production Engineering division of the Production department.	f4) Production and Scheduling Section.
g) None	g) Production Services Department.
g1) Laboratory Division.	g1) Quality Control section.
g11) Materials Engineering branch.	g11) Physical laboratory.
g12) Chemistry branch.	g12) Chemical laboratory.
g13) Test and evaluation branch.	g13) Testing laboratory.

U.S. Naval Gun Factory	National Forge & Ord.Co.
h) In the Production Dept.	h) Mechanical maintenance section.
i) In the Production Dept.	i) Electrical section.
j) In the Production Dept.	j) Welding and cutting tools.
3) Fiscal Department	3) Financial Division
a) Administrative office (staff assistance)	a) None
b) Accounting division.	b) Accounting section.
b1) Payroll branch.	b1) Payroll sub-section.
b2) Timekeeping system.	b2) Section of the Personnel Dept. of the Manufacturing Division.
b3) Costs branch.	b3) Costs Section.
b4) Stores returns branch.	b4) None.
c) Tabulating services Division.	c) None
d) Disbursing Division.	d) Treasurer Department.
e) None	e) Taxes & Government controls.
4) Purchase branch of the Control division of the Supply Dept.	4) Purchasing Division.
5) None	5) Testing Machine Division.
6) None	6) Sales Division.
7) Industrial Relations.	7) None
a) Labor relations.	a) Personnel Dept.of the Manufacturing Division.
b) Training.	b) Personnel Dept. of the Manufacturing Division.

U.S. Naval Gun Factory	National Forge & Ordnance Co.
c) Wage.	c) Personnel Dept. of the Manufacturing division.
d) Placement.	d) Personnel Dept. of the Manufacturing Division.
e) Employment.	e) Personnel Dept. of the Manufacturing division.
8) Public Works Department Design, inspect and maintain public works and public utilities.	8) Mechanical Maintenance Section of the Production Services Dept. of the Manufacturing Division.
9) Medical Department	9) None
a) Medical care.	a) None
b) Physical examinations.	b) None
c) First aid.	c) First aid.
d) Preventive medicine.	d) None
e) Industrial hygiene	e) None
10) Planning Department Administer its budgetary program and allocate funds.	10) Financial Division
11) Supply Department Procure, store and issue materials and equipment. Storage and distribution point.	11) Supply Stores section, of the Material Control Dept. of the Manufacturing Division.
12) Inspection Department Test and inspect material manufactured or procured.	12) Inspection section of the Material Control Dept. of the Manufacturing Division.

c)

POSITION OF PRODUCTION PLANNING IN THE ORGANIZATION

In the organization of the U.S. Naval Gun Factory, "Production Planning" is in the Production Engineering Division of the Production Department.

A simplified chart will show this location better. This chart is No. 8.

In the organization of the National Forge & Ordnance Co., "Production Planning" is in the Engineering division, under the supervision of the Chief Engineer.

A simplified chart will show this position more clearly. This chart is No. 9.

The Naval Gun Factory is greatly concerned over means of securing coordination and utilization of all requirements of production. This is the main reason why production planning, which deals with methods, processes and machines involved in manufacture, and with how to perform the operations, is located in the Production Department.

On the other hand, we observed when we studied the National Forge & Ordnance Co., that to the "Chief Engineer", head of the Engineering Division was delegated a large amount of authority, responsibility, and work. I think these facts are the reasons why production planning was put in the Engineering Division.

Both factories do not have an "Industrial Engineering" division, where the "Production Planning" function could be placed.

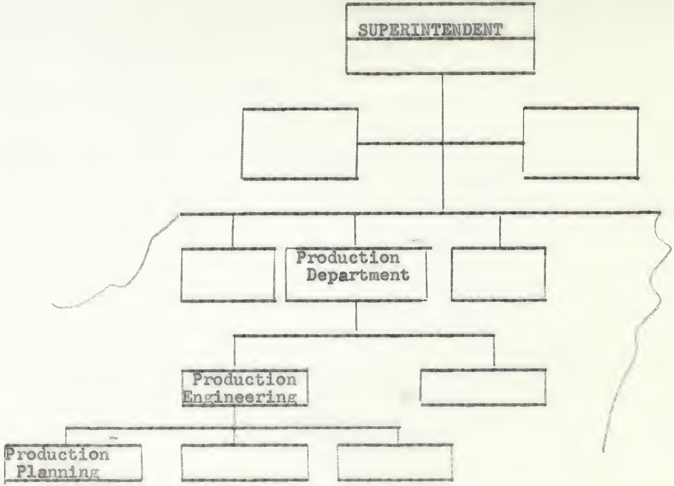

SUPERINTENDENT
Production Department
Production Engineering
Production Planning

CHART NO. 8 - POSITION OF PRODUCTION PLANNING IN THE U.S. NAVAL GUN FACTORY

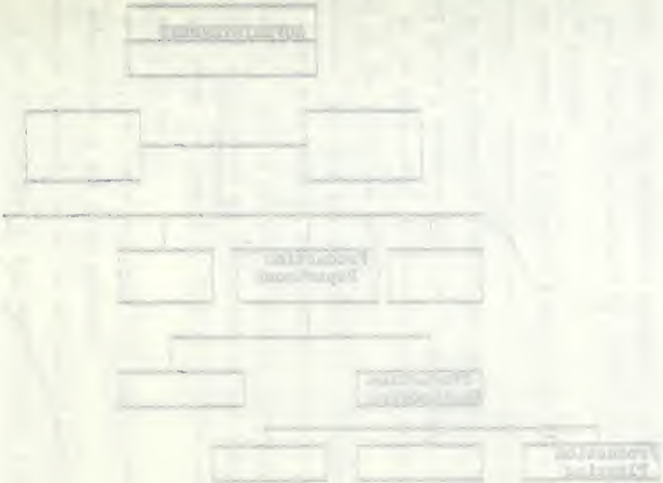

Superintendent
Production Department
Production Engineering
Production Planning

CHART NO. 4 - POSITION OF PRODUCTION PLANNING IN THE U.S. NAVAL GUN FACTORY

An Industrial Engineering Division in the Manufacturing Department of the National Forge & Ordnance Co., would be the best place to locate the "Production Planning Section", without a great alteration in the actual organization.

In the Naval Gun Factory, we could have an Industrial Engineering Division in the Production Department, subdivided into three branches: Production Planning, Plant Layout, and Motion & Time Study.

Today, Industrial Engineering should be looked upon as an essential part of every industrial organization.

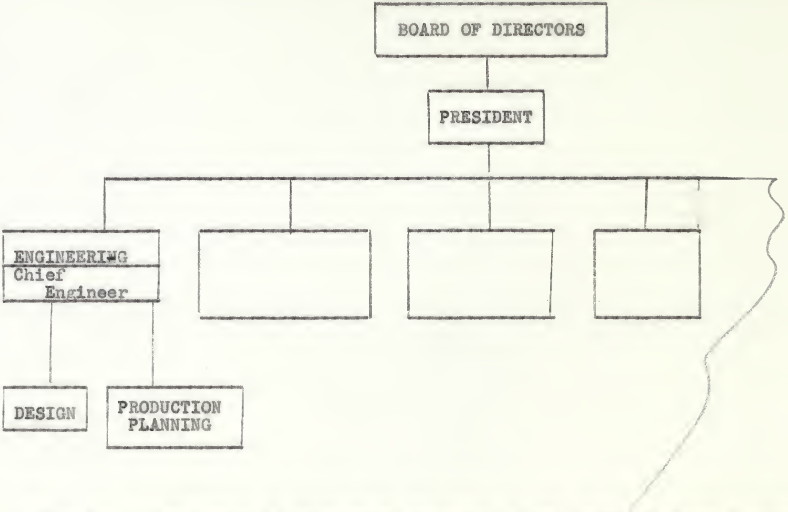

BOARD OF DIRECTORS
PRESIDENT
ENGINEERING
Chief Engineer
DESIGN
PRODUCTION PLANNING

CHART NO. 9 - POSITION OF PRODUCTION PLANNING IN THE NATIONAL FORGE & ORDNANCE CO.

d)

COMMUNICATIONS BETWEEN THE PRODUCTION PLANNING FUNCTION AND OTHER BRANCHES OF THE ORGANIZATION

In the National Forge & Ordnance Co., the Engineering Division prepares the drawings and bill of materials, from which the standard process sheet is made in Production Planning Department. In the Naval Gun Factory, the Engineering Division prepares the Project Prospectus which provides all necessary information to plan for manufacturing.

The Project Prospectus establishes communications to the Planning,Engineering, Production, Supply, Public Works and Inspection Departments. The Project Prospectus is an improvement found from the experience of the various departments to be necessary.

From the office of the General Superintendent of the Manufacturing Division the forms are distributed to the different sections in the National Forge & Ordnance Co. From the office of the head of the Production Department the forms are sent to the shops supervisors.

As these two plants have completely different missions, the communications among the various branches must be fitted to the needs of the organizations.

II - COMPARISON OF THE OPERATION OF THE INDUSTRIAL ENTERPRISES

a) MANUFACTURING THE PRODUCT.

The manufacturing process will be compared in three distinct parts:

1 - Manufacturing the ingot.
2 - Manufacturing the gun barrel forging.
3 - Manufacturing the gun barrel.

1 - Manufacturing the ingot.

Both factories make their own steel. As a result, they are able to control the quality of their steel.

In the National Forge & Ordnance Co., no steel is poured until the chemical laboratory of the Quality Control Section of the Manufacturing Division has checked the analysis and approved it.

In the Naval Gun Factory the procedure is the same.

The furnaces in the Naval Gun Factory have a maximum production of 100 tons of steel every 24 hours. These furnaces are limited by the amount of electric power which can be produced by the Naval Gun Factory, when operating on a three shift basis.

In the National Forge & Ordnance Co., the melting furnace can produce two heats each shift, or four ingots. This furnace must operate at night to conserve on the demand from the electric company.

There are some variations in the dimensions of the ingot:

Dimensions	N.G.F.	N.F.&O.
Maximum length	11'1.5"	13' 5"
Length of the octagonal part	8'	10' 9"
Maximum diameter(octagon)	30"	28.125"
Minimum diameter(octagon)	22"	22"
Length of the cylindrical part	33"	32"
Diameter of the cylindrical part	18.96"	19"

The Naval Gun Factory makes the metal molds for casting the ingots in the Pattern Shop.

The National Forge & Ordnance Co. uses metal molds with adequate hot tops, but does not manufacture them.

2 - Manufacturing the gun barrel forging.

U.S. Naval Gun Factory	National Forge & Ordnance Co.
a) Forging temperature 2,100° F.	a) Forging temperature 2,250° F.
b) 2,000 ton-steam-hydraulic forging press.	b) 1,250 ton die high speed forging press.
c) The ingot is balanced by means of a porter bar.	c) 10,000 lb. straight line manipulator.
d) The forging operation is discontinued when the ingot has cooled to about 1550°F.	d) The forging operation is stopped when the temperature drops below 1800°F.
e) X-ray machine for radiographic inspection of the ingots.	e) Magnaflux inspection for checking forgings for defects due to improper cooling after forging,

U.S. Naval Gun Factory	National Forge & Ord.Co.
	and for determining non-metallic inclusions, cracks, laps, etc...
f) Ultra-sonic testing equipment to detect discontinuities in steel up to thicknesses of 20 feet.	f) None

3 - Manufacturing the gun barrel.

References: Process Charts - Product Analysis.

U.S. Naval Gun Factory	National Forge & Ordnance Co.
a) The centers are determined on the bench, before starting machine operations.	a) The centers are determined at the Horizontal Centering Machine, before starting machining operations.
b) The centers are obtained by means of a combined drill and counter-sink tool, as an engine-lathe work unit.	b) The centers are obtained by means of a combined drill and counter-sink tool when the barrel is set-up in the Horizontal Centering Machine.
c) When the gun barrel is rough turned a collar is left on the muzzle to serve as support for the heat-treatment.	c) No collar is left.

U.S. Naval Gun Factory	National Forge & Ordnance Co.
d) None	d) Lay-out to drill end for heat-treatment.
e) This operation is not done, instead a collar is left on the muzzle end.	e) Drill 4¼ hole to attach the forging to the fixture so that it can be suspended in the Vertical Heat Treating Furnace.
f) The heat-treatment is done in the Forge Shop.	f) The heat-treatment is made in the Heat-treatment shop within the Machine Department.
g) After Heat-treatment the gun barrel is again transported to Shop R.	g) The gun barrel is already in the machine shop.
h) Quantity inspection at Shop R after heat-treatment in the Forge Shop.	h) None.
i) After the third rough bore, which corresponds to the second hognose, the gun barrel is indicated and runout marked, and then it goes to the engine lathe where it is rough turned to within .003" of the final diameter.	i) After the second hognose the gun barrel is indicated and runout marked, and then it goes to the Radial Expansion operation.
j) After honing the next opera-	j) After honing the next

U.S. Naval Gun Factory	National Forge & Ord. Co.
tion composed of 1 work unit is finish turn in the engine lathe.	operation composed of 4 work units is finish turn, file, polish and cut threads.
k) The threads are cut in a thread mill.	k) This operation was performed as a work unit in the item j.
l) Chromium plating and polishing are done in the Polishing and Plating Shop.	l) The polish treatment is given by special polishing devices which are held by the workers while the gun barrel is rotating in the lathe.
m) The gun barrels are kept in controlled storage at the Heavy Machining and Assembly Division.	m) The gun barrels are kept in controlled storage at the Shipping Department.
n) Number of operations 31.	n) Number of operations 34.
o) Quantity inspections 4.	o) Quantity inspections 2.
p) Quality inspections 8.	p) Quality inspections 6.
q) Movements 38.	q) Movements 42.
r) Temporary storage 0.	r) Temporary storage 1.
s) Controlled storage 2.	s) Controlled storage 1.
t) The distance traveled by the gun barrel, considering that many operations	t) The layout of the plant permits the flow of the product to remain inside

U.S. Naval Gun Factory	National Forge & Ord.Co.
were performed in different buildings is much greater than in the National Forge & Ordnance Co.	of one building, and this is the reason for the great economy in the distance traveled by the gun barrel.

b) PLANT EQUIPMENT

U.S. Naval Gun Factory		National Forge & Ordnance Co.	
1 - Foundry Shop		1 - Melting Shop	
a) Electric Steel melting furnace	2	a) Electric steel melting furnace	1
2 - Pattern and Joiner Shop.		2 - None.	
3 - Forge Shop		3 - Forge Shop	
a) 2,000 ton steam hydraulic forging press	1	a) 1250 ton high speed steam hydraulic forging press	1
b) Porter bar	6	b) Straight line manipulator	1
c) Boilers	-	c) Boilers	2
d) Saws	-	d) Saws	2
4 - Gun Shop		4 - Machine Department	
a) Boring machines	28	a) Boring machines	7
b) Engine lathes	25	b) Engine lathes	7
c) Rifling machines	4	c) Rifling machines	8
d) Honing machines	4	d) Honing machines	2
e) Planers	2	e) Planers	3
f) Grinders	9	f) Grinders	2

U.S. Naval Gun Factory		National Forge & Ord. Co.	
g) Drills - - - -	3	g) Drill - - - -	1
h) Milling machines -	1	h) None	
i) Thread milling machines - - -	2	i) None	
j) Shapers - - - -	3	j) None	
k) Lapping machines -	3	k) None	
l) Broach machine for rifling - - - -	1	l) None	

c) LAYOUT OF THE PLANTS

When we are considering the Naval Gun Factory with 188 buildings over 125 acres we must remember that the 21 shops are engaged in a multitude of tasks, since the mission of the factory is very diversified. As a conclusion we can state that in general the machines in the shops are grouped in accordance with the type of operation they perform. This means that all engine lathes are installed in one section, boring machines in another, etc...

Thus we can say that, in general, the Naval Gun Factory uses "layout by process".

In the National Forge & Ordnance Co., on the other hand, the machine tools are laid out by the "production-line method", in the sequence in which they are used.

III - COMPARISON OF THE PAPER WORK INVOLVED IN THE PRODUCTION PLANNING FUNCTION OF THE ENTERPRISES.

a) Standard Process Sheet

U.S. Naval Gun Factory	National Forge & Ordnance Co.
1 - Code	1 - Code
PRNC - 972a (Rev.1048)	Form No.12 9-45-3000M
2 - Purposes	2 - Purposes
a) To specify all production operations in their proper sequence, following a pre-determined processing method.	a) To specify all production operations in their proper sequence, follow a pre-determined processing method.
b) To determine material identification and quantity.	b) None
c) To determine tools and gages necessary.	c) None
d) To determine man-hour allowances for manufacturing operations and set-up time.	d) To determine operation estimated time, including the set-up time.
e) To assign work to shops and to functional groups within the shops.	e) To indicate the shop where the operations will be done and the equipment which will be used.

U.S. Naval Gun Factory	National Forge & Ord. Co.
3 - Responsibilities.	3 - Responsibilities.
a) Issued by the head of the Production Dept. who exercises line direction of the entire manufacturing processes, and gives the "approval".	a) Issued by the Chief Engineer who takes all responsibilities in the matters concerned with design and production planning.
b) "Examined by" the head of the Production Engineering Division of the Production Department.	b) None
c) "Checked by" by the head of the Planning and Processing Branch of the Production Engineering Division.	c) None
d) "Prepared by" the head of the Processing Section of the Planning and Processing Branch.	d) None
e) The information concerned with schedule estinates is given by the head of the Schedule Section of the Planning and Processing Branch, who assumes the responsibility for it.	e) None

U.S. Naval Gun Factory	National Forge & Ord.Co.
4 - Standard Operation Procedure.	4 - Standard Operation Procedure.
a) The process sheet is based on:	a) The process sheet is based on:
a1) "Work Authorization Form"	a1) "Sales Order" giving the "manufacturing authorization".
a2) "Project Prospectus".	a2) Bill of Materials.
a3) Included in a2.	a3) Blue prints.
b) The process sheet is made out by the Heavy Machining and Assembly team, of the Processing Section.	b) The process sheet is made out by the "planner clerk" of the Production Planning Dept.
c) After being approved by the head of the Production Department, the process sheet is forwarded to the supervisor of the Heavy Machining and Assembly Division.	c) The process sheet is forwarded to the superintendent of the Manufacturing Division.
d) After being reviewed by the supervisor of the Heavy Machining and Assembly Division the process sheet is forwarded to the foreman of Shop R (gun shop).	d) After being reviewed by the superintendent, the process sheet is forwarded to the supervisor of the Machine Dept. and then to the foreman of the Machine Shop.

U.S. Naval Gun Factory	National Forge & Ord.Co.
5 - Drawing of the form	5 - Drawing of the form
a) Heading	a) Heading
a1) Code	a1) Code
a2) Title	a2) None
a3) Sheet____of____	a3) None
a4) Serial number	a4) None
a5) Sheet dated	a5) None
a6) Supersedes sheet	a6) None
a7) Prepared by	a7) None
a8) Checked by	a8) None
a9) Examined by	a9) None
a10) Approved - date	a10) None
a11) None	a11) Customer Order.
a12) None	a12) Customer name.
a13) Job order(bottom of the sheet)	a13) Shop order
a14) Completion date(bottom of the sheet)	a14) Promised
a15) Material identification. (bottom of the sheet)	a15) Steel
a16) Quantity(bottom of sheet)	a16) Number of pieces
a17) Drawing and piece name. (bottom of sheet)	a17) Description
a18) None	a18) Treatment
b) Body	b) Body
b1) Shop number	b1) Machine number
b2) Tools and gages	b2) None

U.S. Naval Gun Factory	National Forge & Ordnance Co.
b3) Machine group number.	b3) Machine number.
b4) Operation Description.	b4) Name of operation.
b5) Schedule date.	b5) Promised (head of sheet).
b6) Machine load hours.	b6) Estimated time.
b7) Total labor hours.	b7) None
b8) Estimated Cost.	b8) Estimate sheet(a separate sheet which has the code NF&OCo Form 264)
c) Bottom	c) Bottom (this sheet does not have bottom)
c1) Material Identification and quantity.	c1) Description and number of pieces(head of the sheet)
c2) Order number.	c2) Shop order (head of the sheet)
c3) Drawing and piece number.	c3) Description (head of the sheet)
c4) Schedule date, concerning stock, drawings, tools, forgings and dies.	c4) None
c5) Starting date.	c5) None
c6) Completion date.	c6) Promised (head of the sheet)
c7) Quantity.	c7) Number of pieces (head of the sheet)

U.S. Naval Gun Factory	National Forge & Ordnance Co.
c8) Manufacturing lot size.	c8) None
c9) Assembly drawing number.	c9) None
c10) Drawing revisions.	c10) None
d) Back Sheet.	d) Nothing is printed on the back of the sheet.
d1) Summary for schedule & cost.	d1) None.
d2) Summary cost data by shop.	d2) None
d3) Actual operating time.	d3) None.

In the form used by the National Forge & Ordnance Co., it was noted that the form was set-up in order to obtain a logical and definite sequence of operations performed on a certain product at a determined machine and at an estimated time obtained from existing data. The form is very simple.

The estimated costs, to be checked later with the actual costs as computed by the Accounting Department, are obtained from a special form called an "Estimate Sheet" made after preparing the "Standard Process Sheet".

A considerable amount of time is saved and great simplicity is gained in the preparation of the process sheet by the procedure used in the National Forge & Ordnance Co. The weak points observed in the "Standard Process Sheet" of the Nation-

al Forge & Ordnance Co. are:

1 - One column to specify the tools, jigs, fixtures and special gages, for production operations.
2 - The estimated time should be divided in two columns:
    1) Time to perform the operation.
    2) Time for set-up.
3 - One column to indicate the number of pieces finished in each operation in a certain unit of time.
4 - The head of the form should include:
    1) Prepared by
    2) Approved by
    3) Date issued
    4) Date sup'd
    5) Assembly No.
    6) Sub-assembly No.

The great advantage of the sheet is its simplicity.

On the other hand, the Standard Process Sheet used in the Naval Gun Factory is very complex. This sheet, however, accomplishes entirely the purpose for which it was designed.

Considering that this sheet is used for the following purposes, its complexity is justified:

1 - Plan and specify all production operations.
2 - Develop time and cost requirements.
3 - Determine lot sizes.
4 - Ascertain materials and tooling needs.
5 - Assign work to shops and to functional groups within the shops.

6 - Identify materials to be used and quantity.

7 - Accumulate date on manufacturing experience.

b) Process Chart - Product Analysis

1 - Purposes.

In both factories the uses of this chart would be the same and they are:

1 - To help in planning for a product or layout.

2 - To verify the necessity of doing a particular job before attempting to improve it.

3 - As a guide in the over-all analysis of plant operation.

2 - Responsibilities.

In the Naval Gun Factory this chart is issued by the Methods Branch of the Management Division of the Production Department.

In the National Forge & Ordnance Co., this chart is made out in the Production Planning Department under the responsibility of the Chief Engineer, head of the Engineering Division.

c) Operators Instruction Sheet

In both organizations this chart gives details of the particular operation.

In the National Forge & Ordnance Co., the chart shows a sketch of the piece and the standard time for one piece,

besides the necessary details of the operation.

A characteristic of this sheet in the National Forge & Ordnance Co. is its use as a Time Record, and for cost accounting and payroll purposes.

In the Naval Gun Factory it is also largely used in the shops. Details of each particular operation and the sequence of the steps are written on the drawing concerned with the operation, which also contains the dimensions and tolerances pertaining to the operation.

The type of chart used in the Naval Gun Factory is a very good example of a chart for detailed instruction.

besides the necessary details of the operation.

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In the Naval Gun Factory it is also largely used in the shops. Details of each particular operation and the sequence of the steps are written on the drawing concerned with the operation, which also contains the dimensions and tolerances pertaining to the operation.

The type of chart used in the Naval Gun Factory is a very good example of a chart for detailed instructions.

SECTION FOUR

BRAZILIAN NAVAL GUN FACTORY

1 - History.

Though the idea of manufacturing guns in Brazil is an old one, the first definite step towards its realization was taken at the end of 1939, under the pressure of the second world war.

A Brazilian Mission headed by Comdr. Ayres Fonseca Costa (now a Vice-Admiral) was sent to the United States, with the objective of reporting on the possibilities of installing in the Rio de Janeiro Navy Yard the additional equipment needed for the manufacture of medium caliber guns.

The main factor of success of the mission was the help of the U.S. Navy, through which the Brazilian Mission received advice, was able to visit the Naval Gun Factory in Washington, received drawings and specifications for the manufacture of the 5"/38 double purpose guns, and could place orders for the equipment needed when export restrictions came as a result of the war.

It must be recalled that the Brazilian Gun Factory was considered then as a U.S. Navy project and granted a high priority, without which most of the orders could not have been even accepted by the manufacturers.

In spite of all difficulties brought forth by the international situation, the project went through, and by the end

of 1943 the Brazilian Mission could return home to begin the installation of the shops.

The first years were particularly difficult. The war was still on and deliveries were very much delayed. The raw materials, which could not be purchased in Brazil, were ordered as early as 1942 and yet most of them were not delivered until the end of 1945.

The development phase of the Naval Gun Factory up to the finishing of the first gun can be summed up by the following steps: installing, organizing, training and manufacturing.

The Naval Gun Factory is equipped for the manufacture of 5"/38 double purpose guns, mounts, and ammunition including shells, cartridge cases, and fuzes.

2 - Factory Location.

The Naval Gun Factory is located in the Rio de Janeiro Navy Yard where its installations cover an area of 98,300 square feet.

The primary reason for installation there was the possibility of using all facilities and industrial services of the Navy Yard, such as the Foundry, Forge, Electroplating, and Welding shops.

The reduction of the cost of installation was therefore substantial and had to be considered as very important at the beginning.

Considering the space existing on the second and third floors of the buildings, the area being used by the Naval Gun of 1943 the Brazilian Mission would return home to begin the installation of the shops.

The first years were particularly difficult. The war was still on and deliveries were very much delayed. The raw materials, which could not be purchased in Brazil, were ordered as early as 1942 and yet most of them were not delivered until the end of 1945.

The development phases of the Naval Gun Factory up to the finishing of the first gun can be marked up by the following steps: installing, organizing, training and manufacturing.

The Naval Gun Factory is equipped for the manufacture of 5"/38 double purpose guns, mounts, and ammunition including shells, cartridge cases, and fuzes.

2 - Factory location.

The Naval Gun Factory is located in the Rio de Janeiro Navy Yard where its installations cover an area of 28,700 square feet.

The primary reason for installation there was the possibility of using all facilities and industrial services of the Navy Yard, such as the Foundry, Forge, Electroplating, and Welding shops.

The reduction of the cost of installation was therefore substantial and had to be considered as very important at the beginning.

Considering the space existing on the ground and third floors of the buildings, the area being used by the Naval Gun

Factory totals 138.600 square feet. This area is not all reserved for shop work space, but includes also office and storage space.

The factory has all its equipment installed in one building, with the exception of the equipment for forging ingots, which is installed in the Navy Yard Forging Shop.

3 - Market.

The market is only the national market represented by the armed forces.

4 - Transportation.

Transportation facilities most commonly used:

1) Maritime transportation.
2) Railroad to the most important industrial centers of the country.

5 - Power and Fuel. Electric power and fuel are taken from the Navy Yard.

6 - Labor.

Labor is drawn from the city area which is one of the most important industrial centers of the country. The employee is hired for a specific job and he is not expected to work outside of his trade.

A 40 hour week is established by law and the work week consists of five days of eight hours each and one day of six hours.

For hours in excess of 40 hours per week, the employees are entitled to overtime.

A great difficulty in organizing has been the restricted number of foremen and skilled workers.

The installation of a professional school receiving boys from 14 to 18 years old, and training them through a three year course, is considered as a long range solution of the problem. The first class of apprentices will be ready at the end of 1951.

The school teaches the fundamentals of mathematics, physics, and technology, and trains the apprentices in a variety of jobs before specializing them in the last year. As a result of these methods of vocational education, fewer errors are made in the choice of specialized workers.

In accordance with established policy, individual rate increases are made by promotion.

7 - Source of Principal Raw Materials.

For bar stock the factory is supplied in the Rio de Janeiro market or, in some cases, by purchasing in the United States. A minimum amount capable of supplying the shop for one year at the present rate of production is always kept in stock.

Billets can be ordered from "Volta Redonda" and "Belgo Mineira" which are steel mills in the country.

Stock material is bought in the United States and a reasonable amount kept in stock.

All special tools, such as jigs and fixtures, are now made by the factory. A minimum of standard tools is kept in stock.

The program of the factory includes the manufacture of carbide tipped and high speed steel tipped tools, including milling cutters.

The alloy steels are imported from the United States. All other kinds of iron to be used in the foundry, such as cast iron, white cast iron, malleable iron, and high test cast iron are obtained in the country.

I - DETERMINATION OF THE ORGANIZATION OF THE BRAZILIAN NAVAL GUN FACTORY

a) Structure, Line of Authority, Degrees of Responsibility and Corresponding Duties.

Reference: Chart No. 10

The factory, though located in the Navy Yard, is under the direction of the Bureau of Ordnance, which in Brazil is called"Navy Ordnance Directory"

The affairs are administered by a "Director", a naval engineer officer.

There are two main departments:

a) Industrial

b) Administrative

The Industrial Department takes care of work directly related to production. The Administrative Department deals with personnel, purchasing, and general management.

Its organization is of the functional type. This type of organization breaks the job of the old line foreman into four parts:

a) Preparation of work for the machine.

b) Supervision of machining.

c) Inspection.

d) Maintenance.

The orders and directions are issued from the Industrial Department.

This type of organization requires a greater specializa-

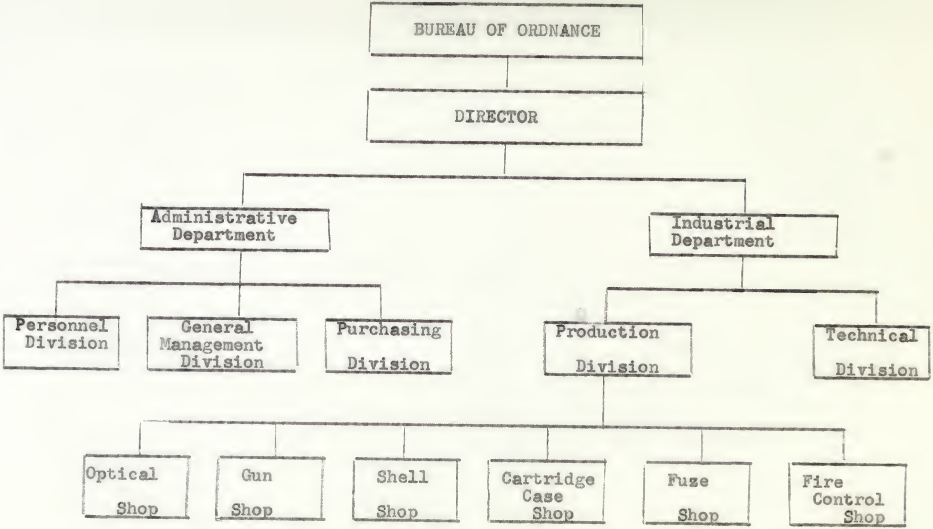
BUREAU OF ORDNANCE
DIRECTOR
Administrative Department
Industrial Department
Personnel Division
General Management Division
Purchasing Division
Production Division
Technical Division
Optical Shop
Gun Shop
Shell Shop
Cartridge Case Shop
Fuze Shop
Fire Control Shop

CHART NO. 10 - STRUCTURAL ORGANIZATION CHART

tion in the skills and abilities of those responsible for the supervision of work.

The Industrial Department is divided into two divisions:

a) Technical Division
b) Production Division

The functions of the Technical Division are:

a) Preparation of drawings and blueprints.
b) Preparation of specifications.
c) Preparation of publications.
d) Preparation of technical instructions.
e) Preparation of photographs.
f) Preparation of operator's instruction sheets.
g) Preparation of bills of material for the supply department which procures materials.
h) Provision of technical guidance to other government establishments and private industrial plants.
i) Preparation of estimates of the cost of proposed work.
j) Supervision of apprentice training program.
k) Preparation of scheduling dates.
l) Performance of inspection and tests.
m) Maintenance of laboratory for inspection of tools and gauges, and for precision measurement.

The functions of the Production Division are:

a) Manufacture of ordnance equipment in accordance with the operator's instruction sheets issued by the Technical Division.

b) Development and installation of effective methods of production.

c) Assistance to other government establishments and private industrial plants in connection with manufacture of ordnance.

d) To obtain from the Personnel Division of the Administrative Department the necessary number of workers to accomplish the job orders.

e) To obtain from the Technical Division all details, instructions and drawings necessary to clear up the manufacturing of some ordnance piece or equipment.

f) Carry on a continuing program for the modernization and improvement of machinery and tooling.

g) Operate the plant's tool cribs.

h) Take care of the safety of the plant.

i) Take care of the maintenance of machine tools, materials handling, and buildings.

j) Take care of the maintenance of the electrical equipment.

The Administrative Department is divided into three divisions:

a) Personnel Division

b) Purchasing Division

c) General Management

The duties of the Personnel Division are:

a) Maintain basic civilian personnel records and prepare reports.

b) Provide tests and examinations for personnel placement.
c) Analyze personnel needs of the factory.
d) Recommend policy and procedures concerning placement.
e) Wage administration.
f) Administer programs of services for employee and management benefit.
g) Provide services for promotions, demotions and separation actions.
h) Merit rating.
i) Vacations.
j) Recreation.
k) First aid.
l) Time-keeping.
m) Plant-guards.
n) Fire protection.

The duties of the Purchasing Division are:

a) Procure from commercial sources services and materials for manufacture and maintenance operations.
b) Determine methods of commercial procurement.
c) Select vendors.
d) Prepare orders and contracts.
e) Administer funds.
f) Maintain records.
g) Take care of stores.

The duties of the General Management are to:

a) Advise and assist the management in making improvements.

b) Keep the Director informed on current work programs.

c) Provide assistance and guidance in personnel management and in administrative services.

d) Furnish technical assistance in meeting personnel, budgetary, fiscal and administrative management problems.

e) Administer the budget.

f) Prepare and present budget justifications.

g) Provide fiscal wervices for the factory.

II - DETERMINATION OF THE OPERATION OF THE BRAZILIAN NAVAL GUN FACTORY

a) Manufacturing of the Product

1 - Introduction

The installation of the machines was begun at the same time that work was being organized, men taught and trained. In order to develop interest for the work being done, some of the parts of the gun were brought into production.

To the considerable amount of work already being carried by the very few engineers in the factory was added the problem of substituting materials for the ones specified in the drawings. This led to the casting forging and heat treating of ingots that in many cases would only have called for the purchase of materials of current use in the United States.

As was said before, the Naval Gun Factory is equipped for the manufacture of 5"/38 double purpose guns and mounts, and ammunition (including shells, cartridge case and fuzes); but to remain within the scope of thisthesis, the product studied will be the gun barrel.

2 - The manufacturing processes will be studied in three distinct parts:

1 - Manufacturing the ingot.

2 - Manufacturing the gun barrel forging.

3 - Manufacturing the gun barrel.

1) Manufacturing the ingot.

The Navy Yard makes its own steel. There are installed two electric furnaces of the arc type. Their nominal capacities are 10 and 6 tons. Ingots are cast into modern types of molds purchased in the United States. Steel analyses are made in the chemical laboratory of the foundry.

Special alloys are imported from the United States.

The chemical composition of the steel required is the same as is used in the National Forge & Ordnance Co.

The dimensions of the ingot are the same as those used in the Naval Gun Factory.

2) Manufacturing the gun barrel forging.

From the foundry the ingot is taken to the forge, which is an other building in the Navy Yard. In this building the major unit is a 3,000 ton "Eumuko" Hydraulic Forging Press.

There are two furnaces for pre-heating and one for heating. Preheating treatment is considered to be some thermal treatment involving a slow rate of heating. Heat-treatment is much faster.

The process used is the following:

a) 0 Hour - Fire the first pre-heating furnace and put in two ingots.

b) 10 Hour - Fire the second pre-heating furnace and put in two ingots.

c) 20 Hour - Remove the ingots from the pre-heating furnace number one and place them in the heating furnace. Lower the temperature of pre-heating furnace No. 1, to receive two more ingots.

d) 29 Hour - Remove the two ingots from the heating furnace and forge to a 19½" octagon in the press.

e) 30 Hour - Remove the two ingots from pre-heating furnace No. 2, and place them in the heating furnace. Lower the temperature of pre-heating furnace No. 2, to receive two more ingots.

Based on the above process and the actual equipment of the forge shop, we can have two 5"/38 barrels forged at every 10 hours.

3) Manufacturing the gun barrel.

Reference: Layout of the plant.

The factory has all drawings, tools and operator's instruction sheets made in accordance with the english system of measures; and all workmen are being familiarised with it and with the general drafting rules followed in the United States. Threads, fits and allowances follow the American standards. Whenever it is possible, the same symbols are used.

The machines are generally of a size above the actual need for the manufacture of 5"/38 gun.

The actual rate of production is 18 gun barrels per year.

a) Before the radial expansion

The forgings are rough turned on a Niles 30" Heavy Forge Lathe made by The General Machinery Co. of Hamilton, Ohio.

There is not a special machine to determine centers. The forgings are rough turned at the breech, spotted for a steady

rest, faced at the ends, and opened up for a rough bore.

The forgings are rough bored in one boring machine made by the Cincinnati Machine Co., Cincinnati, Ohio. Three successive borings are made to get the final dimension of 4.652" before the radial expansion.

b) Heat treatment

The heat-treatment is done in a vertical furnace 5' in diameter and 30' deep. This treatment consists of normalizing, quenching and drawing. The gun barrel is supported in the heat-treatment by means of a collar left on the muzzle end.

Straightening after heat-treating, when necessary, is carried out at one 500 ton Hydraulic Straightening Press manufactured by The A.B. Farquhar Co.

c) Radial expansion.

Special equipment is used similar to those used at the Naval Forge & Ordnance Co.

The forging, after the introduction of the arbor and packing, is expanded in separate pressure stages. The first stage corresponds to a pressure of 79,210 p.s.i., and the last to 45,200 p.s.i.

d) After radial expansion

After radial expansion the operations are done in the following sequence:

d1) Turning to dimensions:

Maximum diameter: 13.100" ± .010"

Minimum diameter 8.050"

The test specimens are cut from the breech end with a thickness of 1.50" to determine whether the alloy steel will meet the physical requirements.

d2) Finish bore to the final diameter of 4.99".

d3) Inspection with a star gauge.

d4) Bore out chamber to 5.30" diameter and a length of 28.65", starting from breech. This operation is performed on the Niles Boring Machine.

d5) Inspection.

d6) Grind the chamber.

d7) Finish turn in the Niles engine lathe to the prescribed dimensions.

d8) Cut threads, in the Niles engine lathe. Snap gauges are used to check the thread dimensions.

d9) The gun barrel is rifled, using a white rifling head and a grooved bar. The number of cutters is 45.

d10) Polish after rifling.

d11) The extractor slots are milled in the breech end.

d12) The key way is cut and the threads interrupted.

d13) Chrome plate the bore.

The equipment consists of a chrome tank, a wash tank, and a polishing head.

b) Plant Equipment

All the equipment has been bought in the United States.

All ingots are made in the Foundry Shop.

All forgings are made in the Forging Shop.

All special tools, such as jigs, fixtures, and gauges are now made in the factory.

Standard tools are bought in the open market.

A laboratory maintained in connection with the inspection of gauges and tools, including the testing of optical elements and instruments, is equipped for any kind of precision measurement.

Summary, showing in each shop of the factory the machines required to manufacture the product being studied:

1 - FOUNDRY SHOP

1 - Electric melting furnace, capacity 10 tons.

1 - Electric melting furnace, capacity 6 tons.

1 - Furnace transformer.

1 - Pouring Pit.

1 - Ingot heating and soaking pit.

1 - X-ray Machine.

Note: A chemical laboratory and a metallurgical laboratory are available in this shop.

2 - FORGE SHOP

1 - 3,000 ton Hydraulic Forging Press.

2 - Porter bar

2 - Pre-heating furnaces.

1 - Heating furnace.

3 - GUN SHOP

1 - Niles 30" Heavy Forge engine lathe.

1 - Niles 30" Boring Machine.

1 - 42" x 20' American Super-productive engine lathe.

1 - 42" x 60' American Super-productive boring machine.

1 - Niles 6" Rifling machine.

1 - Electric Vertical Cylindrical furnace.

1 - Horizontal Boring Machine.

1 - 500 ton Hydraulic straightening Press.

c) Layout of the Plant

The installation covers an area of 98,300 square feet. This area is not all reserved for shop work space, but includes stores and tool rooms.

The shops engaged in the manufacture of ordnance equipment are grouped into three major categories:

a) Foundry Shop
b) Forging Shop
c) Naval Gun Factory
  c1) Gun Shop
  c2) Shell Shop
  c3) Cartridge Case Shop
  c4) Fuze Shop
  c5) Optical Shop
  c6) Fire Control Shop.

The items (a) and (b) are component parts of the Navy Yard.

In our layout we will consider only the machine tools of the Gun Shop involved in the manufacture of the gun barrel. The machines are in general grouped according to the type of operation they perform.

III - DETERMINATION OF THE PAPER WORK INVOLVED IN THE BRAZILIAN NAVAL GUN FACTORY

a) Standard Process Sheet

We do not have, in our factory, a special form of process chart-product analysis. The description of the product is made by a collection of blueprints. In some cases we have a verbal description of the process to be followed.

The Process sheet is, however, a good way to describe the method prior to performance, listing the work required to modify a product in a logical sequence of operations.

Without the process sheet we do not have in a simple form the important summary of:

a) Operations
b) Materials
c) Tools
d) Man-hour allowances
e) Set-up time
f) Work stations
g) Estimated cost

The process sheet is an aid in obtaining the best process before beginning the work.

b) Process Chart-Product Analysis

"A process chart-product analysis is a graphic means of portraying the separable steps of the procedure involved in performing the work required to modify a product from one

stage of completion to another.

"Process-charts-product analysis should be made whenever possible for all materials, prior to the inception of production, to aid in obtaining the best possible process and layout before the beginning of work.

"In all cases of plant layout and process planning, the process for the contemplated components or products should be made in connection with the plans for layout and used to obtain the best possible process and layout; that is, least handling, least number of operations, least scrap, best control, and smallest workable in-process inventory." [1]

OPERATORS INSTRUCTION CHART

Reference: Figure No. 9.

This type of chart is the one most used in our factory. Details of each particular operation and the sequence of the steps are written as well as the drawing or sketch related to the operation with all necessary symbols, dimensions, and tolerances.

Based on technical knowledge and experience, and on records of previous work, the most efficient procedure for each operation is established in detail.

It should be noted that an operator's instruction chart is set up for technical purposes as a standard plan of performance for an operation on a part piece or assembly.

---

1. Mundel, M.E., "Motion and Time Study Principles and Practices," New York, Prentice Hall.

stage of completion is apparent.

"Process-charts-product analysis should be made whenever possible for all materials, prior to the inception of production, to aid in scheduling the best possible process and layout before the beginning of work.

"In all cases of plant layout and product planning, the process (or the continuous improvement of process) should be made in connection with the plans for layout and used to obtain the best possible process and layout: i.e., least handling, least number of operations, least storage, best control, and smallest workable in-process inventory."[1]

OPERATORS INSTRUCTION CHART

Reference: Figure No. 9.

This type of chart is the one most used in our Company. Details of each particular operation and the sequence of the steps are written as well as the drawing or sketch related to the operation with all necessary symbols, dimensions, and tolerances.

Based on technical knowledge and experience, and on records of previous work, the most efficient procedure for each operation is established in detail.

It should be noted that an operator's instruction chart is set up for individual purposes in a standard plan of performance for an operation on a part prior to assembly.

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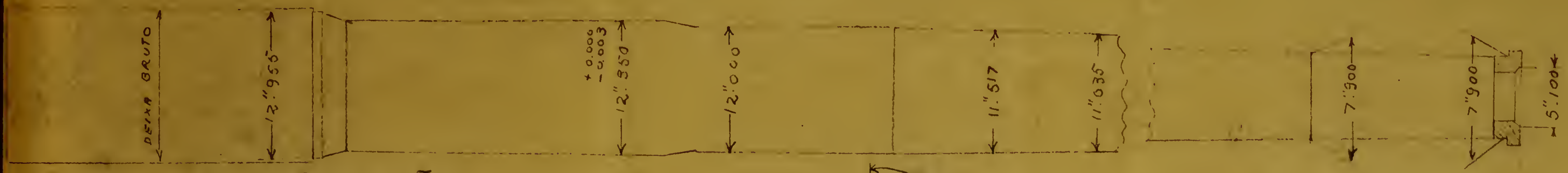
1. Mundel, M.E., "Motion and Time Study Principles and Practices," New York, Prentice Hall.


DEIXA BRUTO
12".955
+0.000
−0.003
12".350
12".000
11".517
11".035
7".900
7".900
5".100
20"000

OPERAÇÕES

1 COLOCAR O CANHÃO ENTRE CENTROS

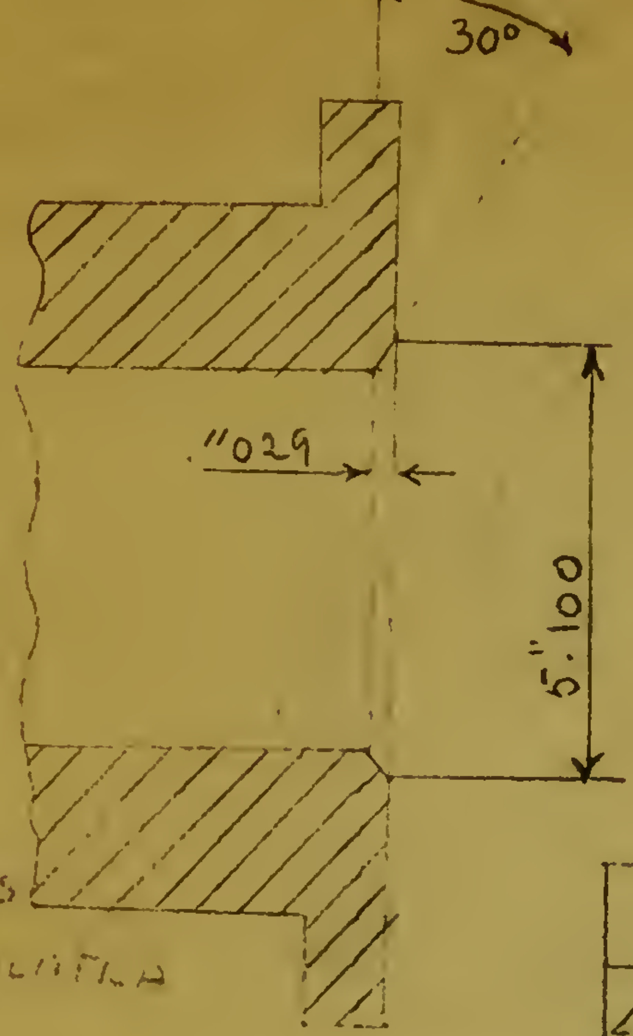
2 VERIFICAR A EXCENTRICIDADE

3 — MEDIR TODOS OS COMPRIMENTOS A PARTIR DA FACE DA CULATRA

4 TORNEAR O CILINDRO DE 12".350 MAIS 0".000 MENOS 0".003 ATÉ 12".500 MAIS OU MENOS 0".020 DO CORTE DA CULATRA

5 TORNEAR O CILINDRO DE 7".900 MAIS OU MENOS 0".005 ENTRE 1'3' E 17'9 DO CORTE DA CULATRA

6 CHANFRAR A BOCA A 30°, A [illegible] DE 0.029 DE MODO [illegible] DIÂMETRO [illegible] DO CHANFRO SEJA DE 5".100



REVISÕES

LETRA	NÚMERO	DATA

APROVADO O. Cunha 10/1/46
VERIFICADO 9/1/46
DESENHADO Edenir 9/1/46
COPIADO

FOLHA DE OPERAÇÕES
CANHÃO DE 5" NGF. MOD 1
TORNEAMENTO

FABRICA DE ARTILHERIA
DA
MARINHA
1946

REFS. USN. 170.040 (F1-14-9-[illegible])

ESCALAS: 1:10; 1:3

50.00[illegible]

These charts, prepared by the Technical Division of the Industrial Department, are issued to the shop for the instruction of foremen and operators.

SECTION FIVE

RECOMMENDATIONS FOR INSTALLATION OF PRODUCTION PLANNING IN THE BRAZILIAN NAVAL GUN FACTORY, BASED UPON THE STUDY DONE IN THE PREVIOUS CHAPTERS

1 - Introduction.

The history of modern factory systems culminated in the automatic machines of today, producing great numbers of parts, so nearly alike that they are interchangeable in any mechanism with perfect results.

Mechanization is not enough, however. The human element continues to be indispensable and the most important part of the situation.

The issuing of an order to the superintendent of the Manufacturing Department does not insure that the order will be carried out.

The production difficulties must be eliminated before starting the work. An economically sound and workable plan establishing how production is to be achieved must be traced.

It was the purpose of this thesis to show the importance of planning for production, and to arrive at suggestions on how to introduce this technique in a manufacturing plant.

2 - Industrial Engineering.

Production planning is one phase of the very large field of Industrial Engineering.

Industrial Engineering involves a great number of activities, a complete discussion of which would require an entire volume. A definition given here, at Purdue, is enough to show its complexity:

"Industrial Engineering is that branch of engineering wherein special knowledge of the methematical and physical sciences and applied psychology together with the principles and methods of engineering analysis and design, acquired by professional education and practical experience, are used in order to solve, in a scientific manner, the problems of designing and controlling an integrated, industrial, human group activity, the related physical facilities, and the accompanying pattern of inter-relationships." [1]

3 - Why do we need a Production Planning System?

Production Planning came to be looked upon as an essential part of every industrial organization. Its main purpose is the design of processes, determining methods, operations, and sequences of operations. Every person in this activity is there to make it possible for those in the shop to attain greater efficiency, and to secure the best utilisation of the equipment and the plant as a whole.

In a general way we can say that in planning the production we are going to:

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[1] Department of General Engineering, Purdue University, 1951.

a) Determine the best way to do the job.
b) Select the best kind of machine tool for it.
c) Issue instructions to the shop regarding the proper method of doing it.

With this system we are taking the matter of planning out of the worker's hands and leaving all of his free time for productive labor.

If the function of planning is left to the worker, he not only takes up part of his time in doing the planning, but may not reach as satisfactory a solution as the planner. If this function is considered to be a worker's duty, every time the job has to be performed the planning procedure must be outlined again. There will, also, not be records of the processes and methods used in the plant.

To select the machines the new job can be studied regarding the machine tools available in the plant so that the machine which most nearly fits the requirements will be used. Sometimes an alternate machine can be considered, to perform the job in consideration.

All of the points that have been discussed are intended to show how much a well organized Production Planning Department helps the management of a plant.

Based upon the comparative study done between the National Forge & Ordnance Co. and the U.S. Naval Gun Factory, an organization chart for the Naval Gun Factory, in Brasil, will be outlined in order to locate the proposed production planning function in this industrial enterprise.

I - RECOMMENDATIONS FOR THE ORGANIZATIONAL STRUCTURE AND POSITION OF PRODUCTION PLANNING IN THE ORGANIZATION

References: Charts Number 10 and 11.

Following the Chart No. 10 (structural) of the Brazilian Gun Factory, we can see that its affairs are administered by the Director, a naval engineer officer, through the heads of the two departments:

a) Industrial.
b) Administrative.

It is recommended that its affairs be administered by the Director, a naval engineer officer, through the heads of four departments:

a) Finance.
b) Engineering.
c) Production.
d) Personnel.

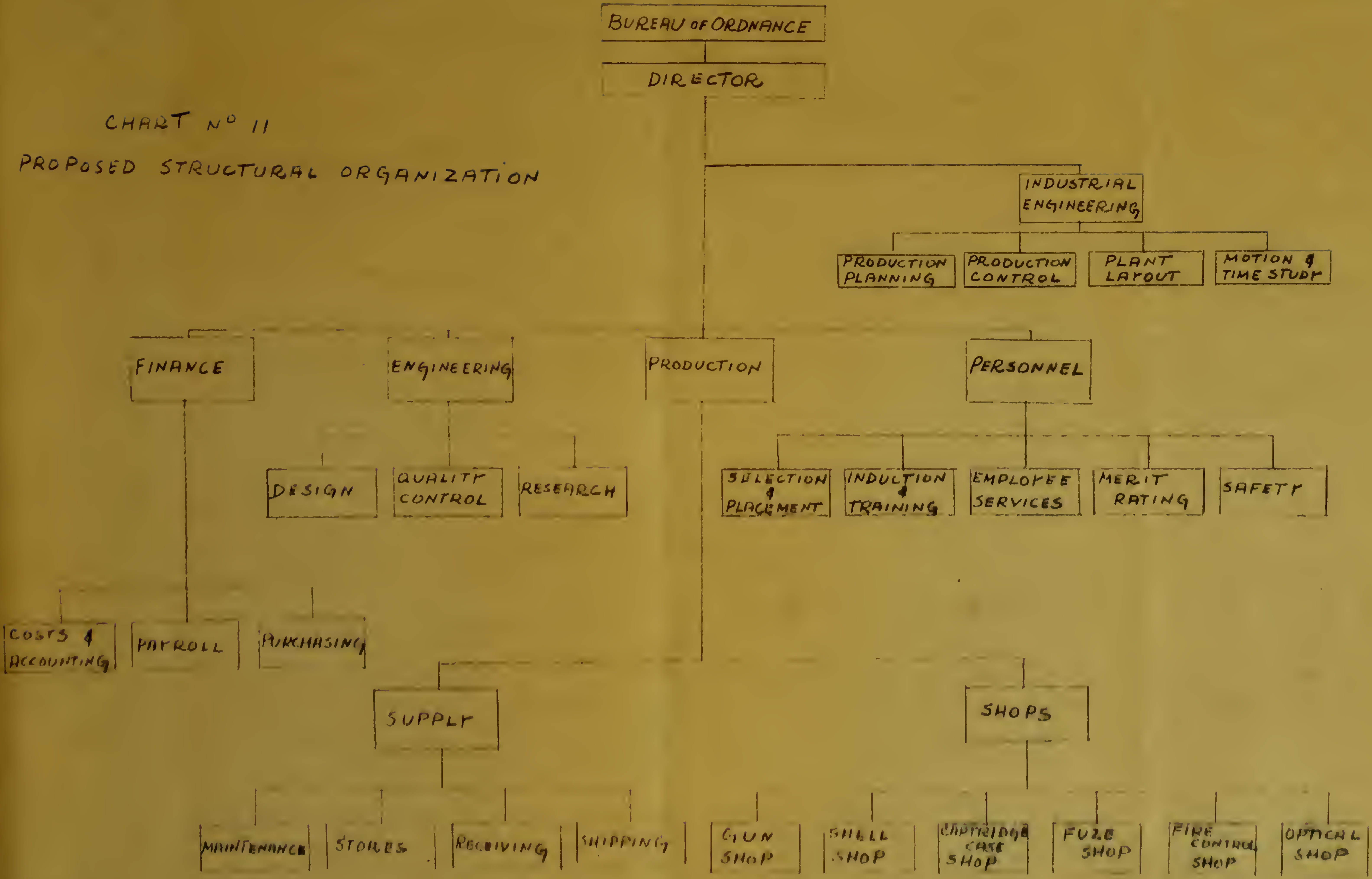
Finance should include:

a1) Costs & Accounting.
a2) Payroll
a3) Purchasing

This department would accumulate and maintain detailed manufacturing, maintenance, and operating expenditures data and records for purposes of complete cost accounting and budgetary control; certify and pay civilian payrolls, and procure from commercial sources services and materials, selecting vendors and preparing orders and contracts.

CHART No 11

PROPOSED STRUCTURAL ORGANIZATION


BUREAU OF ORDNANCE
DIRECTOR
INDUSTRIAL ENGINEERING
PRODUCTION PLANNING
PRODUCTION CONTROL
PLANT LAYOUT
MOTION & TIME STUDY
FINANCE
ENGINEERING
PRODUCTION
PERSONNEL
DESIGN
QUALITY CONTROL
RESEARCH
SELECTION & PLACEMENT
INDUCTION & TRAINING
EMPLOYEE SERVICES
MERIT RATING
SAFETY
COSTS & ACCOUNTING
PAYROLL
PURCHASING
SUPPLY
SHOPS
MAINTENANCE
STORES
RECEIVING
SHIPPING
GUN SHOP
SHELL SHOP
CARTRIDGE CASE SHOP
FUZE SHOP
FIRE CONTROL SHOP
OPTICAL SHOP

In the actual organization the Industrial Department is divided into two divisions:

a) Technical Division.

b) Production Division.

The duties in the American organizations studied which are attributed to "Engineering" are included in the duties of the Technical Division of the Brazilian Naval Gun Factory.

It is recommended that a new department in the Brazilian Naval Gun Factory be established and called the "Engineering Department".

The Engineering Department should include:

b1) Design.

b2) Quality Control.

b3) Research.

This department would design ordnance equipment and improve existing designs; design inspection gages; develop test specifications and supervise tests and inspections of the ordnance equipment; prepare production drawings and specifications; provide parts and lists and information on material; prepare pamphlets; have custody of all drawings; reproduce and distribute drawings, sketches, specifications, standards, ordalts[1], and related data, and supervise all the ordnance research.

The Production Division is one part of the Industrial Department of the Brazilian Naval Gun Factory.

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[1] This is an abbreviation of the term "ordnance alteration".

A new department is recommended, which will keep the same name "Production". The Production Department will include a supply division and a shop division.

The supply division should consist of:

c1) Maintenance.
c2) Stores.
c3) Receiving.
c4) Shipping.

The Shop Division should be sub-divided into:

c5) Gun Shop.
c6) Shell shop.
c7) Cartridge Case Shop.
c8) Fuze Shop.
c9) Fire Control Shop.
c10) Optical Shop.

The production department should be directly related to the manufacture of the product and concerned with the problem of coordinating the elements of production: labor, material, and manufacturing facilities.

The Production Department would manufacture and assemble ordnance equipment, spare parts, tools and accessories; control the manpower distribution within the divisions; provide operating assistance and technical guidance to other government establishments and private plants in connection with manufacture of ordnance; receive, preserve, pack, store, issue, ship or deliver all material from other naval activities, shops and commercial firms; and assure proper factory

maintenance and upkeep.

In the Brazilian Naval Gun Factory, personnel is one division of the Administrative Department.

A separate "Personnel Department" is recommended dealing with:

d1) Selection and Placement.
d2) Induction and Training.
d3) Employee Services.
d4) Merit Rating.
d5) Safety.

The Personnel department would advise and assist in carrying out personnel management; maintain civilian personnel records; analyze personnel needs, recommend policy and procedures concerning selection and placement; provide technical advice and assistance on training matters, conduct programs at its own school; assist in the induction of new employees; provide beneficial suggestions, food services, medical assistance and other morale activities; recommend policy and procedures to rate the merit of employees; and provide plant-guards, fire protection and industrial safety.

In the Brazilian Naval Gun Factory there is no Industrial Engineering Division.

Developments of the last ten years have brought Industrial Engineering to great prominence in industry throughout the United States. This new department would lead to the scientific solution of industrial problems of production, personnel, and management. Industrial Engineering is concerned princi-

pally with plant, equipment, and production methods. Its major objectives are efficiency of manufacture, prevention of waste, and cost reduction.

It is recommended that a new department be established with an advisory function in the organization, including as divisions:

e1) Production Planning.

e2) Production Control.

e3) Plant Layout.

e4) Motion and Time Study.

This department would develop manufacturing processes, determining and recording methods, sequences of operations (including inspections), and tools for each operation; assign work operations to appropriate groups of machines; determine man-hours for set-up and operation; organize the paper work involved in the manufacture with the purpose of control; determine new layouts to get the best work flow; develop standards; and provide technical guidance and assistance in the installation of approved plans.

After a study of the recommended organizational structure which is the relationship between people in the organization required to form an effective working group, we can locate the Production Planning activity in our industrial enterprise.

The organization consists of a number of unit organizations or cells. All organizations grow by additions to these cells. The installation of the Industrial Engineering Department in the organizational structure brought a bundle of these organ-

izational cells. The "Production Planning Division", is then a new organizational cell of the new "Industrial Engineering Department".

The Industrial Engineering Department will have a staff function in the proposed combination line-and-staff type of organization.

The functions of the Production Planning Division will be:

f1) Determination of methods, operations, and sequence of operations.

f2) Determination of inspections, gages, and tools required for each operation.

f3) Distribution of work operations to appropriate shops and to machine groups within the shop.

f4) Estimation of set-up and operation time.

f5) Preparation and release of "standard Process Sheets".

f6) Preparation and release of "Process charts-Product Analysis" and "Operator's Instruction Charts", when necessary.

f7) Preparation of flow diagrams.

f8) Provision of technical advice and assistance on and review of industrial engineering matters.

f9) Development of long-range plans and specific projects aimed at improving the operation of the factory in the field of manufacturing

processes, including the conduct of such studies and investigations.

f10) Assistance in overcoming obstacles arising in the installation of approved plans concerning new methods.

III - PAPER WORK RECOMMENDED FOR THE PRODUCTION PLANNING FUNCTION OF THE ENTERPRISE

1 - Standard Process Sheet.

Reference: Figure No. 10.

a) Definition

A "Standard Process Sheet" is a special form of a process chart-product analysis, listing the work required to modify a product.

b) Code

This is a combination of numbers or numbers and letters to designate the form, in accordance with the "Code Manual" of the factory.

c) Purposes

- c1) To specify all production operations in their proper sequence, following a pre-determined processing method.
- c2) To assign work to shops and to functional groups within the shops.
- c3) To indicate the machine tools or equipment to be used.
- c4) To determine the estimated times for the operations.
- c5) To determine the estimated times for the set-ups.
- c6) To indicate tools and gages necessary.
- c7) To determine part, assembly or sub-assembly identification.
- c8) To determine material identification.

STANDARD PROCESS SHEET

Industrial Engineering Department Brazilian Naval Gun Factory

Part Name ______	Material Identification	Date issued ______
Part No. ______		Date Sup'd. ______
Assembly No. ______		Prepared by ______
Sub-Assembly No. ______		Examined by ______
Quantity ______		Approved by ______

Oper. No.	Operation Description	Shop	Machine	Set-up Time	Operation Time	Pieces per Unit time	Tools

FIGURE NO. 10

d) Responsibilities

d1) The Standard Process Sheet should remain under the jurisdiction of the head of the Industrial Engineering Department, who exercises advisory direction over the entire manufacturing process. He must make a general review of the sheet planned by the Production Planning Division, and send it in to the Production Department.

The head of the Production Department, after making a careful study of the process and the tools involved, issues the sheet to the head of the Shop Division.

The supervisor of the shop, in this particular case the gun-shop, reviews the processing and tooling in order to plan its accomplishment within the shop, to note any discrepancies which may have been overlooked and call them to the attention of the superintendent of the Shop Division, or to propose alternative methods better suited to the shop conditions.

e) Standard Operation Procedure

e1) The Industrial Department should receive the copies of the production drawings, specifications and bill of materials from the Engineering Department.

e2) The Industrial Department should receive from the Finance Department the information concerning the amount of authorized funds allocated to the job in consideration.

e3) Based on the data of the previous items, the Production Planning Division fills out the Standard Process sheet.

e4) After a general review and criticism of the processing and tooling planned by the Production Planning Division, the head of the Industrial Department sends the Standard Process Sheet to the Production Department.

e5) From the office of the Production Department, the sheet goes to the Superintendent of the Shop Division and then to the Supervisor of the shop in consideration (Gun Shop in this case).

e6) The Supervisor of the shop, together with the workers he considers necessary depending on the kind of job to be performed, reviews the processing and tooling specified in the sheet, in order to evaluate its soundness.

e7) When tools, material, prints, Standard Process sheet, and when necessary, the Operator's instruction chart, are available in the shop, the supervisor is ready to give the order to start the job in accordance with the outlined process.

f) Drawing of the form

f1) Head

1) Factory Name

2) Title: Standard Process Sheet

3) Code: In accordance with the "Code Manual" of the factory.

4) Department name.

5) Part name.

6) Part number.

7) Quantity.

8) Date issued.

9) Date superseded.

10) Material identification.

11) Prepared by - Standard Process Sheet clerk.

12) Examined by - (head of Production Planning Division)

13) Approved by -(head of Industrial Engineering Department).

14) Assembly Number.

15) Sub-Assembly Number.

f2) Body

1) Operation number.

The numbers in this column indicate the sequence of operations.

2) Operation Description.

This shows the operations necessary to manufacture the article or part in the sequence established by the column "Operation Number". The work units are listed within each operation in the order required by the process.

3) Shop name or number.

4) Machine name.

After grouping the work units into operations

and arranging the operations in the proper sequence, we now determine the machine tool within a particular shop to perform the work.

5) Set-up time.

The standard set-up time is set operation by operation. The standard times are obtained from existing data if available, or else by time studies. If some alteration takes place in the process or in the equipment, the standard time is again determined from the time studies made by the Motion & Time Study Division of the Industrial Department.

6) Operation time.

The same procedure that was used in item 5 is applied to the determination of the operation time.

7) Pieces per unit time.

This column gives the number of pieces manufactured in a certain unit of time.

8) Tools.

The purpose of this column is to provide the name or code number of the special tools and gages required for each operation. The standard tools and gages will be referred to as "standard" in these columns.

g) Procedure for development of Standard Process Sheets:

g1) The first task that must be accomplished by the Production Planning Department is to obtain the

approximate volume to be produced. This part is the aim.

g2) The analysis of the job means that each separate part must be considered and the work units determined to convert the raw material into a finished part.

g3) Collect all basic data available for the particular industry, in order to make an intelligent choice of equipment.

g4) When the work units have been determined, the next step is to group them in a logical sequence. The machines on which the operations are to be performed and their locations in the shop will have a considerable weight in determining this. In synthesizing we are selecting the style and size of the machine for each operation and grouping the work in the proper order. For each operation the special tools, jigs and fixtures must be indicated.

g5) Make rough cost estimates in order to check on price requirements.

g6) After the Standard Process Sheet has been completed, the Production Planning Department must provide Operator's instruction sheets, for the operations to be performed. When the Standard process sheet and the operator's instruction sheet are completed from the blueprints, all details of

the work have been carefully worked out by the Production Planning Department. Now the "workmen" have only to follow instructions in order to manufacture the product in the most economical fashion. We can now release the technical paper work to the proper personnel and start the installation of the method. In the general procedure for planning the production this phase is called "Application."

g7) The design of a process is not completely finished when the scientific approach based on the above steps, i.e., aim, analysis, basic data, synthesize, check and application, has been gone through just once.

2 - Process Chart - Product Analysis

Reference: Figure No. 11.

a) Definition

"A Process Chart-Product Analysis is a graphic means of portraying the separable steps of the procedure involved in performing the work required to modify a product, from one stage of completion to another".[1]

b) Code

In accordance with the "Code Manual" of the factory.

c) Purposes, How made, How used, and Symbols, are the same as encountered in the "Motion and Time Study" text book of G.E. 128.

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[1] "Motion and Time Study Principles and Practice", M.E. Mundel, Prentice Hall, New York, 1950.

Type of Chart ____________________

Method ____________________ Machine No. __________

Operation ____________________ Operation No. __________

____________________ Part No. __________

Part name ____________________ Chart by __________

Operator ____________________ Date charted __________

f2) Body.

  1) Quantity
  2) Distance
  3) Symbol
  4) Explanation

f3) Summary.

It contains the total amount of each symbol used in the chart.

3 - Operators Instruction Chart.

Reference: Figure No. 12.

a) Definition

The "Operator's Instruction Chart" is a drawing, blueprint or sketch with all necessary symbols, dimensions and tolerances, in which details of each particular operation and the sequence of the steps are written.

b) Code

In accordance with the "Code Manual" of the factory.

c) Purposes

c1) As a standard plan of performance for an operation on a part piece or assembly.

c2) For the instruction of supervisors, foremen, and operators, when necessary.

d) Responsibilities

These charts are the responsibility of the head of the Industrial Engineering Department. They are prepared by the Production Planning Division. The supervisor of the shop

REVISIONS			NAVAL GUN FACTORY	
LETTER	NUMBER	DATE	DEPARTMENT	
			OPERATOR'S INSTRUCTION SHEET	
			OPERATION	
APPROVED BY			DRAWING REFERENCES: R. W.	
DRAWN BY	CHECKED BY		SCALE	DRAING NUMBER

DRAWINGS

DETAILED INSTRUCTIONS IN SEQUENCE

reviews the chart.

e) Standard Operation Procedure

  e1) Based on the blueprints sent from the Engineering Department and on the Standard Process Sheet, the Production Planning Division prepares the chart in cooperation with the motion and time study division.

  e2) After a general review and criticism, the head of the Industrial Department approves the chart and sends it to the Production Department.

  e3) From the office of the Production Department, the sheet goes to the Superintendent of the Shop Division and then to the supervisor of the shop in consideration.

f) Drawing of the form

  f1) Drawing of blueprint or sketches, with dimensions, tolerances and symbols.

  f2) Detailed description of the operations in sequence.

  f3) Title

    1) Factory name
    2) Department name
    3) Operation name
    4) Drawing references
    5) Drawing or blueprint number.
    6) Scale
    7) Revisions
    8) Prepared by
    9) Checked by
    10) Approved by

CONCLUSION

INTRODUCTION OF PRODUCTION PLANNING IN THE BRAZILIAN NAVAL GUN FACTORY

The first step toward the installation of this industrial activity should be an educational movement to sell the principles and purposes of the new industrial activity.

People tend to resist innovation. This may be taken as axiomatic.

The "human factor" is a most important problem to be considered in the integration of "Production Planning" into the organization.

The various steps for installation in a proper sequence will be traced in order to prevent going ahead too fast. Tact, determination, and perseverance will be indispensable until the idea of a production planning system has been sold to the personnel.

In the beginning, the installation usually involves a certain amount of confusion among the workers. It is therefore necessary to prepare the supervisors and workers in advance of the actual change. Adjustments among management personnel will be as serious as among the workers. A change from the original set-up to the new one involves changes in the duties and responsibilities of the top level of management.

The new duties, responsibilities and communications among

the branches of the organization must be studied and planned well in advance of the change. If plenty of time is allowed for the various members of the organization to become accustomed to the plan and to talk it over before installation, many future difficulties will be prevented.

Regardless of how the production planning system is introduced into a plant, the final decisions and the details of the system will depend largely on the type of manufacturing. This was the reason why the recommendations for installation of the activity were based on the study of two factories which are engaged in the same kind of work. The author is convinced that a production planning system will eliminate many of the present difficulties and will reduce production costs in the long run.

When the management is sure of the advantages and wisdom of the new activity, the installation will further cooperation between the several branches in the plant.

From the recommendations now being made, a tailor-made plan will result to satisfy all the requirements.

For the installation of the new activity a committee should be appointed within the factory. The committee should be composed of members of the present Industrial and Administrative Departments, under the effective direction and coordination of the factor's director.

The committee should be informed in detail of the plan's content and have the benefits explained to it. The success of the plan will depend upon the attitude of the committee the branches of the organization must be studied and planned well in advance of the change. If plenty of time is allowed for the various members of the organization to become accustomed to the plan and to talk it over before installation, many future difficulties will be prevented.

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The committee should be informed in detail of the plan's content and have the benefits explained to it. The success of the plan will depend upon the attitude of the committee toward it. Absolutely no doubt of its value must remain after the discussions.

By the installation of this activity in the "Brazilian Naval Gun Factory", the author is sure that production will be improved leaving more time for creative thinking and planning for the future.

Many adjustments will be necessary before the introduction of this new industrial activity is successfully completed.

To quote Lillian M. Gilbreth, a pioneer in Industrial Engineering:

"Processes are orderly procedures, or methods, or rules of ways of doing things. They are complicated enough anyway. We want to make them as simple as we can. They have their operating side and their human relations side.

"In this field unless we have cooperation all the way along the line in getting ideas for simplification of work and putting the ideas into effect, they will not be of any particular value to anyone".

If we get this cooperation "all the way along the line" from the human element, "Production Planning" based on the fundamental principles and practices learned in the United States can be introduced and maintained in the Brazilian Naval Gun Factory.

BIBLIOGRAPHY

Apple, J.M., "Plant Layout and Materials Handling", The Ronald Press Co., New York, 1950.

Mundel, M.E., "Motion and Time Study Principles and Practices", New York, Prentice Hall, 1950.

National Forge and Ordnance Co., "A Manual for Employees", Warren, Penna., 1950.

Public Information Office, "Ordnance Production", Washington, D.C., U.S. Naval Gun Factory, 1951.

Taylor Peck, "Round Shot to Rockets", U.S. Naval Institute, Annapolis, 1949.

BIBLIOGRAPHY FOR ADDITIONAL INFORMATION

BOOKS

Alford, L.P., Bangs, J.R., "Production Handbook", New York, The Ronald Press Co., 1950.

Bethel, L.L., Atwater, F.S., Smith, G.H.E., Stackman, H.A., "Industrial Organization and Management", New York, McGraw-Hill Book Co.,Inc., 2nd Ed., 1950.

Hesse, "Engineering Tools and Processes", New York, D. Van Nostrand Co., Inc., 1941.

Immer, J.R., "Layout Planning Techniques", New York, McGraw-Hill Book Co., Inc., 1950.

Ireson, W.G., "Production Planning and Control", Blacksburg, Va., Pol. Inst., 1943.

Landy, T.M., "Production Planning and Control", New York, McGraw-Hill Co., Inc., 1950.

Officers of the United States Navy, "Naval Ordnance", Annapolis, U.S. Naval Institute, 1939.

Open Die Forging Industry, "Manual of Open Die Forgings", New York, 366 Madison Avenue, 1949.

BIBLIOGRAPHY FOR ADDITIONAL INFORMATION - CONT'D.

PERIODICALS

American Machinist

Factory Management & Maintenance

Machinery

Metal Industry

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